PB-228 045

CAUSES AND RELIEF OF HYPER-EUTROPHICATION OF LAKES

James L. Yount, et al

Florida State Board of Health
Vero Beach, Florida

13 December 1966

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 228 045

051213

FINAL REPORT

FILE COPY

CAUSES AND RELIEF OF HYPER-EUTROPHICATION OF LAKES

Grant Number: WP-00216-06

Former Principal Investigator (and author of main report):

James L. Yount
Chairman, Division of Natural Sciences
Polk Junior College
Bartow, Florida

Principal Investigator (and author of appendix):

Roy A. Crossman, Jr.
Biologist
Florida State Board of Health
Winter Haven, Florida

Sponsoring Institution:

Entomological Research Center
Florida State Board of Health
Vero Beach, Florida

Period Covered by Report

October 1, 1960 - August 8, 1966

Date of Report

December 13, 1966

i.

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

67

SUMMARY AND CONCLUSIONS

There were two principal objectives for this study, one, to find whether artificial aeration of hypertrophic lakes is practically possible as a means of reducing their overall metabolism as measured by gross primary productivity and by insect productivity, and, two, to find whether it is possible to reduce productivity of artificial ponds (inferring lake application) by harvesting living tissue from the ponds and thereby reducing the nutrients available for production.

The first objective was studied on Lake Buckeye in 1961, on Lake Cannon in 1962 and finally on Big Lake Tangerine in 1965 and 1966. There was no indication of even overturn, much less effect on productivity, in Lake Buckeye. There was apparent reduction of productivity as a result of aeration in Lake Cannon, but the more extensive and thorough study on Big Lake Tangerine indicated neither productivity reduction nor reduction of insect populations at all. Therefore we can not recommend this as a practically usable method of reducing hypertrophy in lakes.

The second objective, harvesting living tissue from artificial ponds in order to reduce their productivity, has been studied in six series of ponds, five of which for various reasons did not give data useful for the objective. The sixth series of ponds, however, did give positive evidence that productivity of the ponds which had their plants harvested was reduced over productivity of the control ponds in which the dried and ground tissue from harvested plants was returned to the ponds. We therefore feel that this method is practically useful as a method of reducing hypertrophy in lakes. The chief problems with its use probably would be in engineering, for hyacinths and other floating aquatic plants contain some 95% water, and harvesting them out of the lake by the ton, as would be necessary in hypertrophic lakes, would mean a large drying problem, or else handling large amounts of body water in the plants.

In addition to the present report, some papers already have been published regarding certain aspects of the study not herein reported on. See "List of publications supported by the Grant". Because of the distinct and different nature of the entomological studies under this research program, findings are presented as an Appendix.

INTRODUCTION

Central Florida has many hypertrophic lakes as evidenced by dense populations of algae and midges and by the fact that they are usually anaerobic during much of the summer even though very shallow. This study was instigated because of the nuisance quantities of midges, and it was early recognized that such quantities probably depended on the lakes' hypertrophy (Provost 1956, 1958).

Our initial objectives were two: first, an attempt to reduce the numbers of midges by biological or ecological control, and second, an attempt to reduce the lakes' hypertrophy by limnological means. The obvious preferred method of attack was to render ineffectual human influences on the trophy of the lakes, i.e., sewage industrial wastes, agricultural drainage and the like.

It was felt that chironomids were probably favored in the lakes, for certain species are known to have special ability to endure anaerobic and accompanying conditions, such as the production of methane and hydrogen sulfide (Usinger and Kellen, 1955, Walshe, 1950), whereas their normal predators are probably lacking in such ability (Moore, 1942, Hasler, 1945). Artificial aeration was therefore regarded as a possible method for improving conditions for midge predators and thus possibly reducing midge populations.

Artificial aeration also was regarded as a possible method for reducing the nutrient level of hypertrophic lakes. If reduction or absence of oxygen at the mud-water interface creates reducing conditions and permits the release of greater quantities of nutritive substances than if oxygen is present (Einsele 1936, Mortimer 1941-2), then artificial aeration should enhance precipitation and "locking" of such nutrients in the mud so that they would not be available for the lake metabolism. The influence of living organisms, especially bacteria, however, is not well known, and in fact they may upset the theoretical picture stated above (Hayes and Phillips, 1958).

Where nutrients are available in quantity, "blooms" of algae occur. The magnitude of blooms apparently depends on the duration of reducing conditions at the bottom (Tucker, 1957). Allen and Eden (1946) showed that sufficient continuous aeration results in complete bacterial oxidation of carbohydrates to CO_2 and water, while insufficient aeration results in incomplete breakdown. It would thus appear necessary to aerate a hypertrophic lake continuously during stratification periods in order to have a significant effect on mineralization and oxidation of organic matter. Some of the workers with artificial aeration have used this technique to increase fish production by bringing nutrients to the trophogenic zone (e.g., Hasler, 1957), but it appears that continuous aeration would have the opposite effect ultimately. A major aim of the present study therefore was to attempt to reduce nutrient chemicals in solution in the lake - that is, prevent reducing conditions at the mud-water interface - and hopefully, to reverse the hypertrophication trend in these lakes, by continuous artificial aeration.

It was hoped, therefore, that artificial aeration would help reduce midge numbers directly by allowing fish to penetrate into heretofore impenetrable regions to seek out midges, and indirectly by reducing the phytoplankton nutrients. This use of aeration was to be the chief study, but later, other means of reducing the level of nutrients in lakes were studied to a limited degree and are also reported on here.

THE LAKES

Physico-chemical studies: These already have been adequately covered in this grant's first progress report dated March 1, 1963, pp. 2-5.

Productivity studies: These studies also have been adequately covered in the first progress report, pp. 12-14.

ATTEMPTS TO RELIEVE HYPERTROPHICATION

AERATION: A major objective of this study was to determine whether there was any effect from aeration on the trophic condition of the lakes, particularly whether there was a tendency for reversal of hypertrophy. We have attacked this problem at three different times, during 1961 on the 72 acre Lake Buckeye with a small aeration system, during 1962 on the 328 acre Lake Cannon with a large aeration system, and during 1965 and 1966 on the 30 acre Big Lake Tangerine with a large aeration system. Aeration results on Lakes Buckeye and Cannon have been presented in the first progress report, pp. 6-11, and only the results from the Big Lake Tangerine experiment are included here.

Big Lake Tangerine:

After our apparent success in overturning and seeming reduction of productivity of Lake Cannon, we felt that we needed to use a much smaller lake with much less human influence, so that there would be no doubt whatever that the test lake was being overturned, and so that it would be influenced as little as possible by unknown nutrient factors, such as septic tanks. We chose three lakes for this purpose, both Little Lake Tangerine and Lake St. Claire serving as controls for the experiment to be performed on Big Lake Tangerine. We spent two years, 1963 and 1964, getting the use of these lakes and adjacent land, acquiring funds, buying and testing equipment to be used on the test lake, and most important getting background data on the lakes, as well as continuing other studies reported below in another section.

For this experiment, we purchased three electric compressors, of which two only were in use at any time; this prevented the three compressors from being overworked. These were Quincy Model 240 compressors: the pressure gauge, with the two running, registered about 75 p.s.i., and they produced an approximate volume of 25 c.f.m. each, making a total volume of 50 c.f.m. being forced to the lake. Five plastic aerator lines were placed in Big Lake Tangerine in a radiating manner from a point on the shore near the compressor station, which totalled

3750 feet of aerator lines for air bubbling, with another thousand feet of feeder line carrying air from the compressors to the aerator lines. These five lines almost completely crossed the lake, and were arranged in such a manner that the bubbling would overturn the lake as efficiently as possible. We tested the apparatus' bubbling on 7/3/64 for one hour and noticed a definite sulfide odor over the aerator lines. It was tested again on 9/16/64 for a day. Full time aeration began on 4/14/65 and continued, without stopping, until 3/31/66, on which date the grant terminated.

The test lake, Big Tangerine, is about 30 acres in area and circular, and is connected to the 10 acre, circular Little Tangerine by a shallow canal of about 300 yards length. Little Tangerine has a large water pump on its shore which pumps water from the lake for irrigation of the surrounding citrus groves during very dry periods to prevent damage to the citrus crop. Lake St. Claire is larger, 70 acres in area, nearly circular, also has a large water pump on it, and on March 8, 1965, was connected to a fourth lake by a newly dug shallow canal. It is separated from the Lakes Tangerine by about 1/4 mile distance. Because of its size, Lake St. Claire is exposed to much more wind effect than either of the Lakes Tangerine; in addition, its secchi reading indicates that it usually has a considerably lower phytoplankton density than the Tangerines, and its gross primary productivity was usually lower, probably because of the lower phytoplankton density. Probably as a consequence of all three, larger size, lower phytoplankton density and lower productivity, Lake St. Claire also usually had a great deal more oxygen in its depths and a lower range of oxygen throughout the pre-experimental period than the Lakes Tangerine (Figs. 1-3). It was therefore considered to be a relatively poor lake to use as a control for the experiment, although the measurements were continued on it. This poorness as a control is revealed for example in the oxygen distribution during 1965 and 1966, where the oxygen range picture in St. Claire frequently resembled that in the test lake, Big Tangerine.

Results: As in the case of Lakes Buckeye and Cannon, we attempted to answer two questions: first, did the aeration system overturn the test lake, and second, was there an effect of this aeration system on the general productivity of the lake, and specifically on chironomid productivity. We used various parameters measured vertically as before to test the overturn effectiveness: pH, methyl orange alkalinity, acidity, dissolved oxygen, temperature, and conductivity were measured at various stations in each of the three lakes. Water level was also measured during the period of investigation. It is not only an indicator of rainfall, seepage and evaporation, but also an indicator of the use of the lake water for surrounding citrus groves. Because of much use of the water for the groves especially during 1965, we measured rainfall separately by a gauge located between the Lakes Tangerine where we built a series of ponds and had placed a trailer.

Big Lake Tangerine was clearly overturned thoroughly throughout the period of aeration, from April 14, 1965 to April 1, 1966. We tested the system for one hour on July 3, 1964 and in the area of the bubbles a sulfide odor was very obvious, indicating that overturn was effective. Better evidence that overturn was effective is illustrated by the range of oxygen in Big Tangerine compared to that in Little Tangerine and even in St. Claire (Figs. 1-3). It will be noted that in 1963 and 1964, before aeration, both Tangerines, and St. Claire to a limited degree, commonly showed a vertical oxygen range during the summer of almost 10 parts per million (in the winter, of course, this range becomes much reduced because of natural overturn from temperature, density and wind effects). During 1965 and 1966, the aeration period, the control lakes showed generally a lesser range in oxygen than they had in the previous years, but this reduction is insignificant compared to the small range exhibited by the test, Big Tangerine. In addition, the saturation level of oxygen was not as high in the aerated Big Tangerine as in Little Tangerine, indicating a lack of stability, and therefore of supersaturation, due to overturn.

Temperature ranges (Figs. 4-6) also reveal that overturn was effective. In the pre-aeration period both Lakes Tangerine, and St. Claire to a much smaller degree, showed a wide range in temperature throughout the warm periods of 1963 and 1964, whereas Big Tangerine showed a much narrower range of vertical temperature throughout the aeration period than did Little Tangerine. Lake St. Claire, presumably for the reasons described above, did not show a wide range in temperature; rather it resembled the test lake fairly closely. Conductivity, pH, alkalinity and acidity did not vary sufficiently vertically during the period of the experiment to reveal differences between the lakes that can serve as evidence that the test lake was overturned. Judging by the oxygen and temperature pictures, however, I feel that there is no doubt that the aeration system was overturning Big Lake Tangerine, especially when this is compared to previous years without aeration as well as with the control lakes during the aeration test period.

In order to test whether aeration had significant effect on reducing the trophic level of the test lake below that of the control lakes, and below that of the test lake during the pre-aeration period, we measured gross productivity, secchi visibility, and chironomid standing crop via egg mass deposition, larval samples from the bottom, adult emergence from traps, and pupal casts on the traps at various positions in the three lakes. Water level and rainfall were also measured in order to pinpoint any possible effects of these parameters on productivity and secchi visibility.

During the pre-aeration period, secchi visibility was generally deeper in St. Claire than the Tangerines and both Tangerines' measures were fairly close to one another. This same situation was true throughout the experimental period for both Tangerines, but Lake St. Claire's secchi reading decreased considerably during 1965 and 1966, after the new canal joined another lake to it (March 8, 1965); this decrease indicates increased phytoplankton in Lake St. Claire and this probably was due to the influx of water from the new lake into it. Both the control, Little Tangerine, and the test, Big Tangerine, however, remained fairly high in secchi reading during aeration as well as before it. This indicates a lack of effect on secchi visibility, and therefore phytoplankton density, of the aeration experiment.

Gross primary productivity similarly showed little or no effect of the aeration on Big Lake Tangerine. In general, during 1963 and 1964, Little Tangerine's productivity was somewhat higher than that of either Big Tangerine or St. Claire, and St. Claire's was generally somewhat less than either of the Tangerines. During the aeration period, these same relationships usually held, but there was a great deal more variation from one measure to the next during the period of aeration than before, and St. Claire's productivity rose and stayed almost at the level of the Tangerines. This latter coincides with the time of the entrance of the new canal into St. Claire, and, as already discussed above regarding secchi visibility, presumably this increase in productivity is related to the influx of new water into St. Claire at that time. In sum, there is no clear evidence that aeration was effective in reducing productivity of Big Lake Tangerine.

Our studies on insects in Lakes Tangerine and St. Claire included pupal casts, emergence, egg masses and larval sampling during 1963 through the end of the grant in March, 1966. As can be seen in Appendix Figure 3, these data reveal no reduction effect of aeration on insect populations - in fact, it would appear that aeration somewhat increased, rather than decreased, insect populations in Big Tangerine. There is thus no evidence that aeration was effective in reducing insect populations in Big Lake Tangerine.

Conclusions regarding all aeration experiments:

The Lake Buckeye experiment gave no clear evidence even of overturn, whereas that on Lake Cannon apparently did. The experiment on Cannon also gave apparent indication of a favorable effect on productivity reduction, but insect populations showed no effect. With a bigger aeration system and a smaller, less human-influenced lake, however, Big Lake Tangerine gave clear evidence of overturn, but gave no clear evidence that aeration was reducing phytoplankton populations, gross primary productivity, or chironomid populations. We feel, therefore, that reversal of the trophic state of a lake by artificial aeration is not practically possible.

DIRECT REMOVAL OF NUTRIENTS FROM THE ECOSYSTEM

In September, 1962, we began a new series of studies designed to test the effectiveness on trophic reversal of removing nutrients directly from aquatic ecosystems. The theory behind this was reported on briefly in a talk to the Florida Anti-Mosquito Association (Yount, 1964), and is here somewhat expanded in order to give background thinking for the results below.

Nutrients can be removed from any aquatic ecosystem in two ways, one by sucking up bottom muds and eliminating them from the lake, and two by harvesting, and eliminating from the lake, living tissue, which of course contains nutrients. We have not attempted to study the former, although this certainly appears to be a method worthy of investigation. The second method, harvesting living organisms, has been investigated fairly thoroughly by us and looks promising as a method for reversing the trend toward hypertrophy in aquatic ecosystems.

Thomas (1944, 1965) suggested that harvesting fish, algae, etc. from hypertrophic lakes would be good for these lakes since it would remove nutrients from them. As fish possess high mineral values, this appears to be an excellent possibility for removal of nutrients from lakes, especially since it would require no outlay of tax money. Research is necessary, however, before this can be allowed, to determine what bad effects, if any, might result from permitting commercial fishermen to harvest large quantities of both "coarse" fish and "game" fish from lakes that are used by sport fishermen. This looks like an interesting avenue of investigation to me, and one with as great potential as that of investigating the effects of bottom mud removal from lakes on hypertrophy reversal.

As such knowledge in this area is lacking, however, we placed emphasis on harvesting other organisms, aquatic plants and bacteria, but with the same objective, reversal of hypertrophy.

The organisms we studied were the water hyacinth, Eichhornia crassipes, the water fern, Salvinia rotundifolia, other floating plants to a limited degree, and bacteria that grow on sawdust. Wood waste and other wastes consisting largely of cellulose (sawdust, wood chips, corn cobs, peanut hulls, etc.) are avidly attacked by bacteria where water is available. They thus have the probably very useful property of being a high energy source and simultaneously a poor source of mineral nutrients. According to Allison and Anderson (1951), nutrients such as nitrogen and phosphorus are removed by these bacteria from sawdust - containing soils to such an extent that crops planted there grow poorly, if at all. In fact, heavy collateral fertilization is necessary in order to get benefits from the humus formation of sawdust. It thus appears that cellulose decomposing bacteria compete successfully with crop plants for mineral nutrients in the soil, making these nutrients relatively unavailable for green plant use. The sawdust could be placed in bags and removed and replaced at intervals in order to harvest the organisms decomposing it. Our studies on sawdust quickly gave anomalous results, however, and because of time and worker limitations, were not continued in the present investigation. I believe nonetheless that this method may prove useful, especially since it could be used in cold climates as well as warm ones; it thus offers another seemingly excellent line of investigation.

For our nutrient removal tests, we chose floating plants, chiefly water hyacinth and water fern, because they could be relatively easily harvested from a lake compared to rooted plants and planktonic algae, and they could be enclosed as a mat and anchored wherever we chose in the lakes. Oswald and Golueke and their colleagues (1959, 1962) have harvested large quantities of planktonic algae from sewage oxidation ponds, but this requires considerable equipment and time that the use of floating plants does not require. In addition, the density of algae in even hypertrophic lakes is too low to use their methods, and there would be other difficulties to their use as well. Floating plants have an advantage over planktonic plants, too, in that carbon dioxide is not limiting for them. They thrive in a medium blooming with algae, apparently at the expense of the algae, probably because of their shading out the algae as well as this carbon dioxide availability. We therefore felt that they could be useful for nutrient removal if frequent controlled harvesting were carried out. There may be a possibility of using such plants as fertilizer, livestock feed or even human food as mentioned by Pirie (1960). If so, the expense of harvesting and drying (they consist of some 95% water) may be obviated. Our nutrient removal studies were carried out chiefly in plastic lined ponds, but limited studies were performed also on a lake and two natural ponds. These latter are reported first below.

Harvesting of plants from lakes:

On March 16 to 20, 1964, we enclosed an area of Little Lake Tangerine of about one acre with 1 inch mesh chicken wire to retain floating water hyacinths. On March 25, we placed 125 lbs. of living water hyacinths in this enclosure. Previously we had noticed that wild water hyacinths grew well in this lake, so there was no known reason why the hyacinths placed there would not grow properly. By the middle of May 1964, however, all hyacinths had disappeared or dried up on bushes and weeds near the shore of the enclosure. The lowering lake level during this period showed that a great deal of water was removed from the lake for citrus grove use. We felt, therefore, that this was the chief reason for the disappearance of our hyacinths, i.e., the plants would get caught in the weeds near shore while being blown around by the wind, and as the water level lowered, would die. On May 24-26, 1964 we added more fencing to keep the water hyacinths away from the shore, and added 971 lbs. of new water hyacinths to the enclosure. These plants were dipped up, placed in a large plastic sheet inside a boat and later transferred to the enclosure by dipnet and hand. There was therefore considerable crushing, manhandling and breakage of the plants. We kept a closer vigilance on the lake hyacinth mat from this time, and soon noticed that many hyacinths had half moon-shaped bites taken from the outer leaves, then the floats, and later even the stems and roots disappeared. This situation was at first true only of those hyacinths that were unhealthy, but we soon noticed that such bites were common among the healthy growing hyacinths as well. We suspected that turtles were the culprits and on one occasion, saw a turtle apparently eating a hyacinth, by looking with binoculars from a distance. We then made a few traps - small hyacinth containing enclosures, with a board permitting the turtles to enter but not leave - and only once, on January 29, 1965, captured a small slider, Pseudemys floridana peninsularis, in one of them. By November of 1964, all the living hyacinths we earlier had placed in the enclosures were gone, largely eaten as evidenced by the many half moon-shaped bites in leaves and floats of the hyacinths. Healthy hyacinths, however, continued growing inside the traps where turtles had not gained access. We therefore postulated that we had trained the turtles to eat hyacinths by furnishing them at first with their normal food, hyacinths that were unhealthy from being crushed in moving in large quantity, and with so many of the hyacinths in such a condition, the turtles gradually learned to eat the healthy ones as well as the unhealthy ones. Allen (1938) pointed out that these "sliders" normally eat hyacinths only if the hyacinths are overturned so that the leaves are under water, and as Carr (1952: 278) said, "One can feel only sympathy for the thousands of Florida cooters that inhabit hyacinth-ridden lakes and streams and can only gaze upward at the succulent but upright and unassailable salad, and await the providential upset of a plant!"

We made a small test of this idea by enclosing two Pseudemys f. peninsularis in a tank with 50 lbs. of hyacinths, some of which had been crushed, on 11/24/64. By 11/30/64, almost all these hyacinths had been eaten, when we added another 25 lbs. These in turn had been eaten by April 1965, the winter cold apparently slowing down the turtles' metabolism. There is thus evidently a possibility of training these turtles to eat healthy water hyacinths, and considering the pest nature of the hyacinths, I feel this is an excellent line of investigation for the future. We did not carry this study any further in the present investigation, however.

Harvesting of plants from natural ponds:

On April 23, 1964 we selected two ponds for study, one a small pond, the Salvinia Pond, near Lake St. Claire, which was covered completely by a mat of *Salvinia rotundifolia*, and two the Airport Pond, a water-filled borrow pit near Gilbert Field in Winter Haven. Our original plan was to test the productivity effect in the Salvinia Pond of harvesting Salvinia, using the Airport Pond as a control. Wind ultimately destroyed much of our hyacinths in the Airport Pond, and apparently algae growing on and covering the roots of the hyacinths in the Salvinia Pond reduced their productivity to zero in the later stages of the experiment so that it was not used for its original purpose. I think the data on productivity is useful, however, for it gives a measure of hyacinth growth in natural unfertilized waters; this can be compared to the results reported later from the fertilized artificial ponds. We used three 1/4 m^2 floats protected by 1/4" mesh wire "hardware cloth", half filled with water hyacinths, and growth was measured from time to time. The results are reported in Table I. They are probably low, however, because of too frequent sampling (cf. below).

Harvesting of plants from artificial ponds:

In September 1962, we dug a series of basins of about 10' X 10' area near Lake Lulu in Winter Haven, and lined them with one layer of 4 mil translucent polyethylene. We added well water and three pounds of "milorganite" to each, a sewage sludge with a guaranteed minimum analysis of 5.5% N, 3% P and 0% K. The studies carried out here were exploratory in nature, but gave ideas used later, *viz.*, one, that we must use black plastic rather than translucent because the latter is rather quickly destroyed by light, and two, the location was poor, being near town, so that people punched holes in the ponds, shot holes in a trailer we had parked there, and even set fire, we believe deliberately, to the grass surrounding the area. We soon set up in a new location; nevertheless, our exploratory studies at Lake Lulu showed that we could grow floating plants in these ponds and that their productivity was very high - they doubled in weight within 17 to 39 days, even during the winter.

We next acquired land around Lakes Tangerine and had a series of basins dug there for pond building. These were used for all our pond studies from May 1963 to June 1965 when we set up a series of vinyl, steel supported, 30" high swimming pools that were used until the present study terminated.

Aside from troubles with people, the following were our greatest problems with these ponds: (1) leaking (Table II) - many pond experiments were interrupted because of small, usually unidentifiable leaks in the polyethylene liners (we later used two layers of plastic; and we have had no problems with the vinyl swimming pools); (2) poor polyethylene plastic material - on some occasions, plastic lasted for more than two years, but on others, similar plastic ordered from the same company broke down in months or even weeks (again vinyl has not given us any trouble); and (3) on rare occasions when especially heavy storms occurred in the area, rainwash would enter the ponds and bring with it trash and sand which of course could influence productivity (the elevated pools have eliminated this problem also). In addition to these major problems, after our early Tangerine series had been studied for a time, we realized that our productivity method for lakes, using the dark and light bottle oxygen method, was not valid for these shallow ponds, for much of the productivity was evidently in organisms that grew on the sides and bottoms of the plastic liners, whose photosynthesis and respiration could not be measured in our oxygen bottles. We thus substituted as a measure of productivity, growth of floating plants held in restricted areas on the ponds. Another major problem occurred through unfortunate ignorance on my part - we were advised by an entomologist friend to eliminate certain caterpillars, which were eating the hyacinths in some of our ponds, by dusting the hyacinths with Paris Green, and we dusted every hyacinth in all our ponds. This killed the plants as well as the insects and prematurely terminated two series of experiments. A final problem that occurred during our second year of study on the Lake Tangerine ponds was in the method used for harvesting, weighing and handling the floating aquatic plants for measuring productivity. The first year I did all this myself, and to measure productivity, harvested only those plants in excess of 1/2 the area of the floats in which they grew, i.e., I did not touch any plants other than those excess ones harvested. In addition, I harvested infrequently, only when the floats were completely full. The second year, however, two men measured productivity, and to get better accuracy all plants were lifted out and weighed, so that a more precisely known quantity was returned to grow within the float. In addition, we harvested frequently, once a week rather than about once every three weeks or longer as done earlier. We got very low productivity during this time compared to our earlier studies; I felt therefore, that our too frequent harvesting and too complete handling shocked the growing plants (removal, draining, weighing and return to ponds), whereas earlier, harvest took place infrequently and only on those plants in excess of 1/2 the area enclosed by the floating ring. This presumably left those remaining in the ring with little shock, and the long intervals permitted them to grow to their full capabilities. Henceforth, we reverted to the earlier method, and growth again reached the high rate of the earlier studies.

The aim of the pond studies was to see if we could remove enough nutrients by harvesting the floating plants from a restricted area to reduce productivity generally. For this purpose, we have studied six series of ponds and for various reasons mentioned above, five series did not give satisfactory results. Nonetheless, we got considerable useful data from these five series (Table III). They are taken up below in chronological order.

Series 1: This series of ponds, begun on 5/9/63, gave us useful data only on the growth potential of floating aquatic plants, for the method of productivity measurement was invalid (see above). In addition, however, this series gave us useful experience regarding artificial pond study. In future studies, we were enabled to measure productivity reduction better, by using the floating plants themselves as described above. We eliminated from future studies the measuring of pH, secchi visibility and turbidity, as well as dark-light bottle productivity, for we felt that these measures were not germane to our aim of measuring the effect of harvesting floating aquatic plants on productivity, even though in themselves, they revealed interesting data. We continued to measure water level, conductivity, and net primary productivity by harvest, for these parameters were relevant to this aim: water level to indicate evaporation and rainfall, conductivity to indicate nutrient reduction generally, and harvest to indicate productivity reduction as well as to be the means for performing the reduction.

The first ponds in this series (1, 2, 3, 3A, 4, 4A) were small (9 $ft.^2$ area, 20" deep) and at first were planned to be used for hyacinth growth studies or artificial aeration studies. We soon realized that the latter was a long term project, and thus decided to eliminate the aeration plan, instead using them for further studies on harvesting floating aquatic plants. Ponds A, B, C and D were the same size as the others and were planned to be used for growing midge larvae; we put one egg mass (average egg number 1000) of G. paripes in each, screened them so that no insects could leave, and simultaneously placed water hyacinths in B and C to see if harvesting them would affect the numbers of midges emerging. This study was completely unsuccessful from the midge standpoint, only one adult being taken from the four ponds, but it gave us data for comparing the growth of water hyacinths in screened versus open highly fertilized ponds, discussed below.

The remaining ponds in this series, 5-14, were 10' X 10' squares, and held approximately 2 feet of water. The fertilizer used was 1255 g. of milorganite (5.5 - 3 - 0) and 20 grams of hydrated lime in each; the lime was added because the well water was soft. This resulted in the ponds becoming highly productive or hypertrophic within a week, deep green in color from algae, and possessing vast numbers of midges (cf. Yount, 1966). We then placed water hyacinths or water ferns in them and for a short time got net productivities on a dry weight basis of more than 70 grams $/m^2$/day in one pond (12) and near 60 in all of them. This 70 is equivalent to 623 pounds/acre/day, much higher than any heretofcre reported production of any organism, including agricultural or sewage fed forms (cf. Yount, 1964). This is perhaps due to my harvesting more than 1/2 the hyacinths in the containing ring, for this extreme measure has not been gotten since; but measures of more than 50 g/m^2/day are not uncommon in our studies. What with the experience we had gained on these preliminary studies, we felt we could start a new series of ponds with the expectation of useful results.

Series 2: On 11/7 and 8/1963, we laid new plastic sheets on some of the old ponds (5-12) and filled them with water; on 11/14 we added 20 g. of hydrated lime and 1255 g. of floragon to each, a sewage sludge from Chicago with a guaranteed minimum analysis of 6% N, 3% P and 0% K. On 12/2/63 we added two male and two female Gambusia to each pond for mosquito control, as we had done in all previous pond experiments. These ponds and four new ones (W, X, Y, Z) served for studies on Hyacinth, Salvinia and Pistia harvest. The productivity measures on the floating plants from series 2 never came even close to the earlier measures in series 1. At first, we thought the generally low productivity was due to cold weather (as undoubtedly, some was) but gradually realized that something else was involved. I finally decided it was our new method of too much handling while measuring productivity, as explained above. In ponds W, X, Y and Z, however, productivity measures began in warm weather with high quantitites of nutrients, and even though too frequently harvested, gave fairly high productivities.

The next three series of studies were short-lived, for we dusted the hyacinths used in them with Paris Green. We afterwards tried to salvage the ponds by pumping out all mud and water possible, and re-fertilizing after again filling them, but the plastic soon began to deteriorate, ripping and tearing under the lightest winds. We could not then keep dirt out of the ponds, so these series were all discontinued by June 10, 1965. Before poisoning the ponds with Paris Green on

4/23/65, however, we made a study of chironomid productivity (Yount, 1966) and got some useful data on hyacinth productivity from series 3 and 5. Series 4 unfortunately did not last long enoughto harvest hyacinths. In these three series, we used water hyacinths only, square meter growth areas for the plants, and, in series 4 and 5, used an improved fertilizer, milorganite which contained Fe_2O_3 (6% N, 3% P, 0% K and 4% Fe_2O_3); in addition, we harvested by the old method we had used on series 1.

To summarize briefly, series 3 consisted of the old ponds 5-14 newly lined and built on 11/24/64. By 3/11/65 many caterpillars, kindly identified by Dr. W. H. Lange as Synclita obliteralis (Walker), were noticed, which had cut small portions of leaves, doubled them into a sandwich, and floated around the ponds in them. The productivity of the hyacinths in the ponds where these insects were most numerous was very low, so we decided to eliminate them from all ponds, including the 10 new ones of series 4, which had been built beside those of series 3 on 3/30 and 3/31/65. This poisoning was done on 4/23, and of course terminated both series 3 and 4. Series 5 was an attempt to salvage the ponds from series 3, and thus was again a use of the old ponds 5-14. We did not reline these ponds from series 3, merely cleaned them out and refilled and refertilized them on 4/27/65. Leaks and ripping and tearing plastic, however, discouraged further attempts to use them (cf. Table II).

Series 6, ponds 1-10: We therefore abandoned series 5 on 6/10/65, purchased ten vinyl swimming pools from Sears, Roebuck and Co., and started a new series of studies, series 6, on June 20, 1965. These sturdy pools are still in use (8/12/66). They are steel supported pools, with a diameter of 10 feet, height of 30 inches, and hold approximately 1000 gallons.

The treatment for series 6 was more thorough than for earlier series, and is described here in some detail, so that future workers may use our methods if desirable. We bought dirt, carefully spread and levelled it at all the future pond sites, and tamped and watered it down. It was then thoroughly sprayed with a solution of arsenic trioxide to prevent the growth of grasses through the plastic, which had earlier given us so much trouble with leaks, and the whole area was covered with a sheet of polyethylene plastic. Then the ten swimming pools were erected on the plastic and filled with well water. These vinyl pools are tough and have given no troubles with leakage, so have proven satisfactory for our purposes. I recommend, however, that anyone doing this type of work use instead large steel livestock watering tanks, which are long-lasting, easily drained, very strong, and can be lined with some inert material which can be painted or sprayed on them. On 7/9/65, we added four pounds (1814 grams) of the improved milorganite (6 - 3 - 0 - 4) and 20 grams of hydrated lime to each pool, and on 7/12, placed four pounds of water hyacinths in each in square meter rings, as well as two or three Gambusia.

The plan of study was to investigate the following questions: (1) could we get the high productivity in these ponds that we had gotten in series 1; (2) could we reduce productivity by harvesting, and thereby eliminating from the ecosystem nutrients contained in the bodies of the harvested plants; (3) what is the effect on productivity of adding small amounts of nutrients daily, simulating conditions in a hypertrophic lake; and (4) if there is an increased productivity from this continued addition, could we control it by frequent harvesting of hyacinths; i.e., could we grow hyacinths in sufficient quantity to reverse hypertrophy even though there was nutrient addition. We chose for these purposes four ponds to be used as controls which would receive no additional nutrients beyond the initial 4 pounds, and which would have their hyacinths harvested at intervals to measure their productivity; all harvested hyacinths from the control ponds were dried, ground and returned to the ponds so that as little nutrient as possible would be removed from them. On the other hand, all other ponds had their hyacinths harvested, to measure productivity as in the controls, but the harvested plants were thrown away, thus not returned to the ponds, so that we could see what effect removal of plants from these ponds would have. These latter ponds were divided into two groups, the "test" ponds and the "nutrient addition" ponds. The four test ponds received no additional nutrients and their hyacinths were harvested as frequently as the others and thrown away. Two nutrient addition ponds were chosen from which hyacinths were harvested and thrown away, but after a time, certain amounts of milorganite were added daily to simulate hypertrophic lake conditions. In this case, we added in the aggregate as much milorganite as had been placed in each pond initially, so these nutrient addition ponds in time received eight pounds of fertilizer.

Although the data are insufficient to draw conclusions regarding the nutrient addition ponds, it appears from the productivity data that harvesting hyacinths reduced these ponds' nutrients far enough below those of the controls to considerably slow down the growth rate of the remaining hyacinths, for although small quantities of nutrients were added every day after 9/16/65, productivity remained low. Conductivity (Table IV; Fig. 7) of the test ponds, however, remained considerably higher than that of the nutrient addition ponds whereas their productivity was lower, and I am at a loss to explain why the nutrient addition ponds' productivity was so low. It possibly had to do with microclimate differences, or trace element scarcity in the nutrient addition ponds, perhaps due to greater insect emergence from them for some reason. This clearly should be investigated further, possibly by using screened ponds so emerging insects' nutrients would not be lost.

If the productivity of the test and control ponds only are contrasted (Table V), however, clear evidence of considerable reduction of productivity by harvesting is seen. I think it can be said from these data that harvesting of water hyacinths from the test ponds clearly reduced their productivity, and that harvesting from natural waters can be expected to reduce the productivity of those waters. Further, it seems evident that the present method of controlling the "pest" water hyacinth and other plants by chemical sprays is returning their contained nutrients to the lakes and thus adding to the problem of hypertrophy of these lakes.

The conductivity data do not support this conclusion as well as the productivity data. Perhaps this is because there are other ions (such as CO_2) than those from the milorganite which contribute to the measure. Average conductivities of the test and control ponds, however, do support the conclusion based on productivity, even though exceptions at certain times and in certain ponds are notable.

List of Publications of Research Supported by the Grant

Yount, J. L. 1961. A note on stability in central Florida lakes, with discussion of the effects of hurricanes. Limnology and Oceanography 6: 322-325.

Yount, J. L. 1963. South Atlantic States. Chapter 8 in Limnology in North America, D. G. Frey, ed. Univ. Wisconsin Press, Madison, 734 pp.

Yount, J. L. 1964. Aquatic nutrient reduction - potential and possible methods. Rept. 35th Annual Meeting, Fla. Anti-mosquito Assn.: 83-85.

Yount, J. L. 1966. A method for rearing large numbers of pond midge larvae, with estimates of productivity and standing crop. Amer. Midland Naturalist 76: 230-238.

Staffing

There were four full-time persons working on the grant, the principal investigator, an entomologist, a chemist, and a field aide. Additional part-time personnel have been associated briefly with the study.

Foreign Travel

No foreign travel has been done.

REFERENCES

Allen, E. R. 1938. Notes on feeding and egg laying habits of the Pseudemys. *Proc. Fla. Acad. Sci.* 3: 105-108.

Allen, L. A. and G. E. Eden, 1946. Effect of continuous aeration on bacterial oxidation of organic matter. *J. Hygience* 44: 508-517.

Allison, F. E. and M. S. Anderson. 1951. The use of sawdust for mulches and soil improvement. *U. S. Dept. Agr. circ.* #891: 1019.

Carr, Archie. 1952. *Handbook of Turtles*. Comstock Publ. Assoc., Ithaca, N. Y. 542 pp.

Einsele, W. 1936. Ueber die Beziehungen des Eisenkreislaufs zum Phosphatkreislauf im eutrophen See. *Arch. Hydro*biol. 29: 664-686.

Hasler, A. D. 1945. Observations on the winter perch population of Lake Mendota. *Ecology* 26: 90-94.

Hasler, A. D. 1957. Naturally and artificially (air-ploughed) induced movement of radioactive phosphorus from the muds of lakes. *Unesco Int. Conf.* Radioisotopes 4: 658-675.

Hayes, F. R. and J. E. Phillips. 1958. Lake Water and sediment IV. Radiophosphorus equilibrium with mud, plants, and bacteria under oxidized and reduced conditions. *Limnol. and Oceanogr.* 3: 459-475.

Moore, W. G. 1942. Field studies on the oxygen requirements of certain fresh-water fishes. *Ecology* 23: 319-329.

Mortimer, C. H. 1941 and '42. The exchange of dissolved substances between mud and water in lakes. *J. Ecology* 29: 280-329; 30: 147-201.

Oswald, W. J. 1962. The coming industry of photosynthesis. *Amer. J. Public Health* 52: 235-242.

Oswald, W. J., C. G. Golueke and H. K. Gee. 1959. Waste water reclamation through production of algae. *Sanit. Eng. Research Lab., School of Public Health, Univ. Calif., Berkeley* (Mimeo): 89 pp.

Pirie, N. W. 1960. Water Hyacinth: a curse or a crop? *Nature* 185: 116.

Provost, M. W. 1956. The production of chironomids in the lakes of the Winter Haven area. Preliminary Study. *Fla. State Board of Health, Entomological Research Center, Vero Beach.* 36 pp. (mimeo).

Provost, M. W. 1958. Chironomids and lake nutrients in Florida, *Sewage and Industrial Wastes* 30: 1417-1419.

Thomas, E. A. 1944. Ueber Massnahmen gegen die Eutrophierung unserer Seen und zur Förderung ihrer biologischen Produktionskraft. *Schweiz. Fischerei Zeitung*, #7/8, 8 pp.

Thomas, E. A. 1965. The eutrophication of lakes and rivers, cause and prevention. *Biol. Problems in Water Pollution, 1962, R. A. Taft. Sanit. Eng. Center, USPHS, Cincinnati, Ohio*: 299-305.

Tucker, A., 1957. The relation of periodicity to the nature of the physico-chemic environment with special reference to phosphorus. *Amer. Midland Naturalist* 57: 300-370.

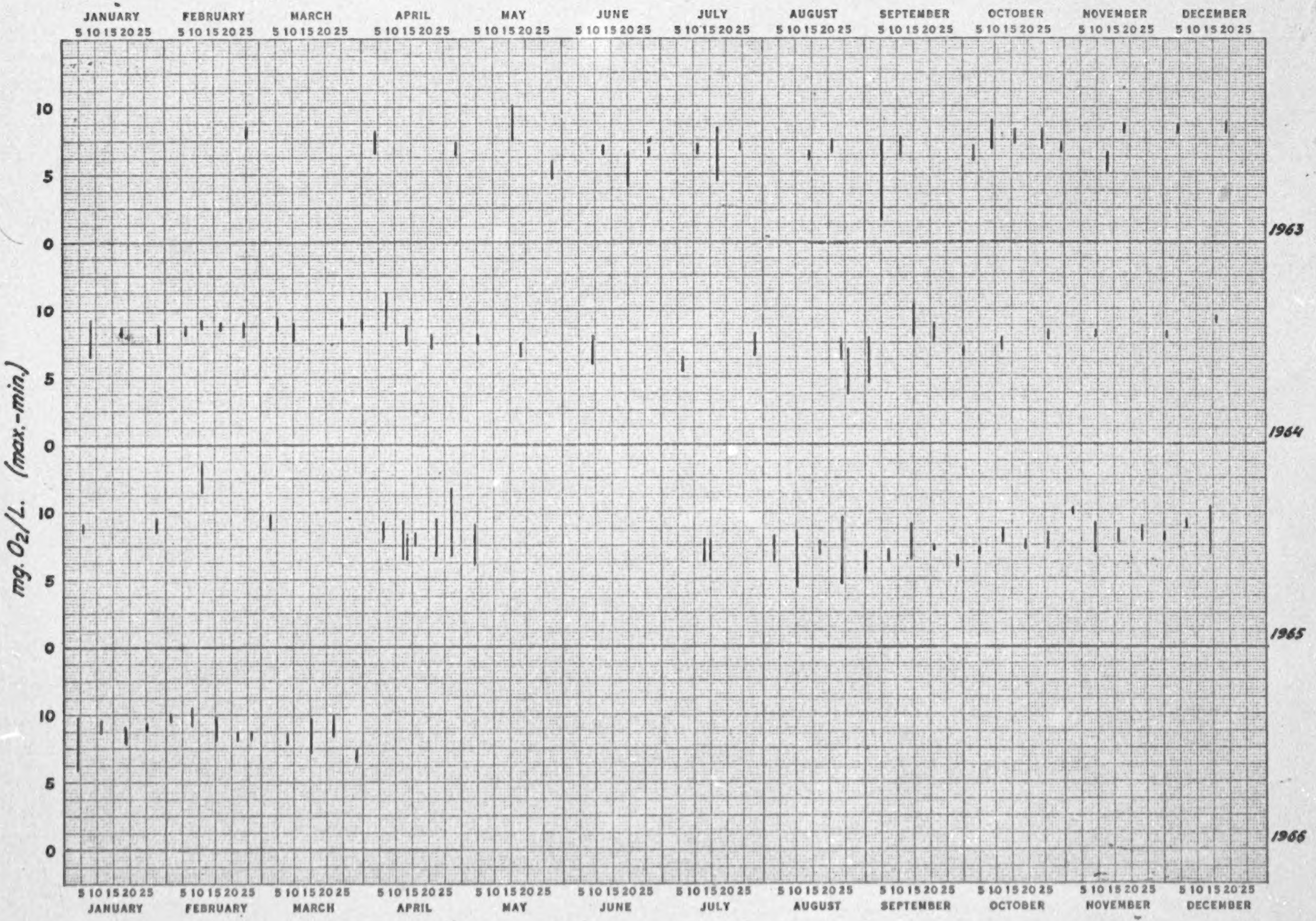
Usinger, R. L. and W. R. Kellen. 1955. The role of insects in sewage disposal beds. *Hilgardia* 23: 263-321.

Walshe, B. M. 1950. The function of hemoglobin in *Chironomus plumosus* under NATURAL CONDITIONS. *J. Exper. Biol.* 27: 73-95.

Yount, J. L. 1964. Aquatic nutrient reduction - potential and possible methods. *Rept. 35th Ann. Meeting Fla. Anti-Mosquito Assn.*: 83-85.

Yount, J. L. 1966. A method for rearing large numbers of pond midge larvae,... productivity and standing crop. *Amer. Midland Naturalist* 76: 230-238.

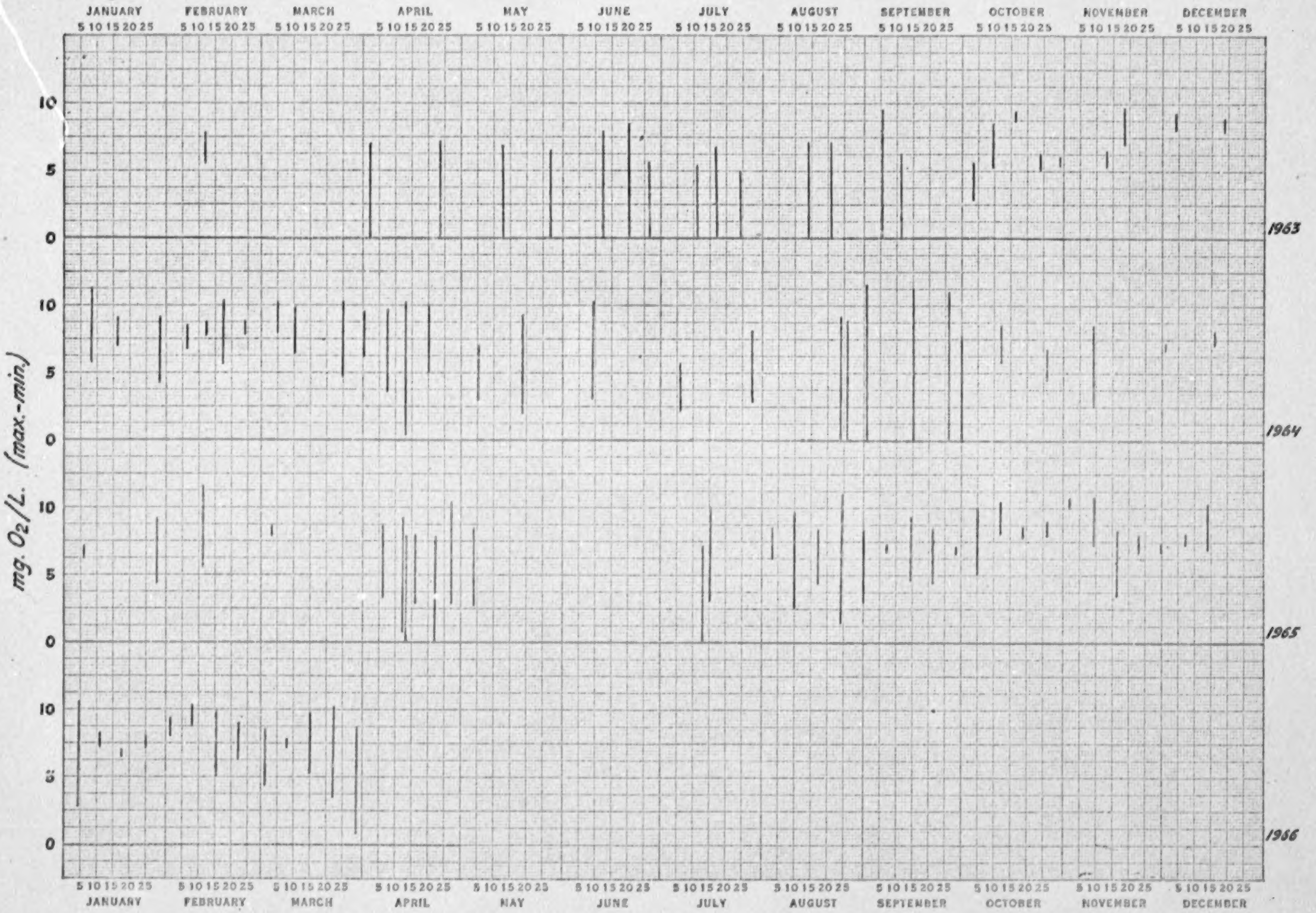
K+E 1 YEAR BY DAYS X 250 DIVNS.
KEUFFEL & ESSER CO.
CALENDAR YEAR
358-142
MADE IN U. S. A.



LAKE ST. CLAIRE

Fig. 1

K+E 1 YEAR BY DAYS X 250 DIVNS. KEUFFEL & ESSER CO. CALENDAR YEAR 358-142 MADE IN U.S.A.

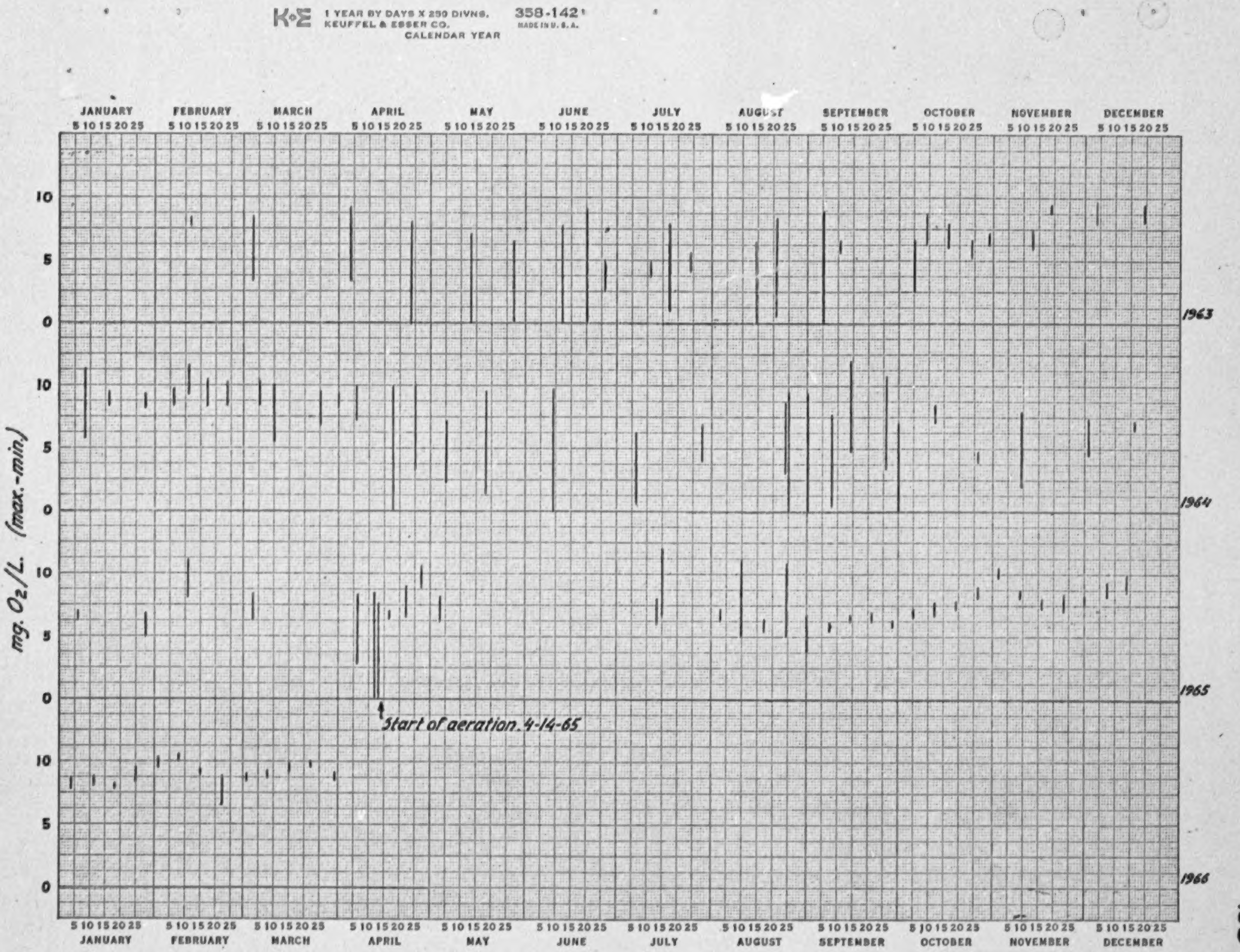


LITTLE LAKE TANGERINE

Fig. 2

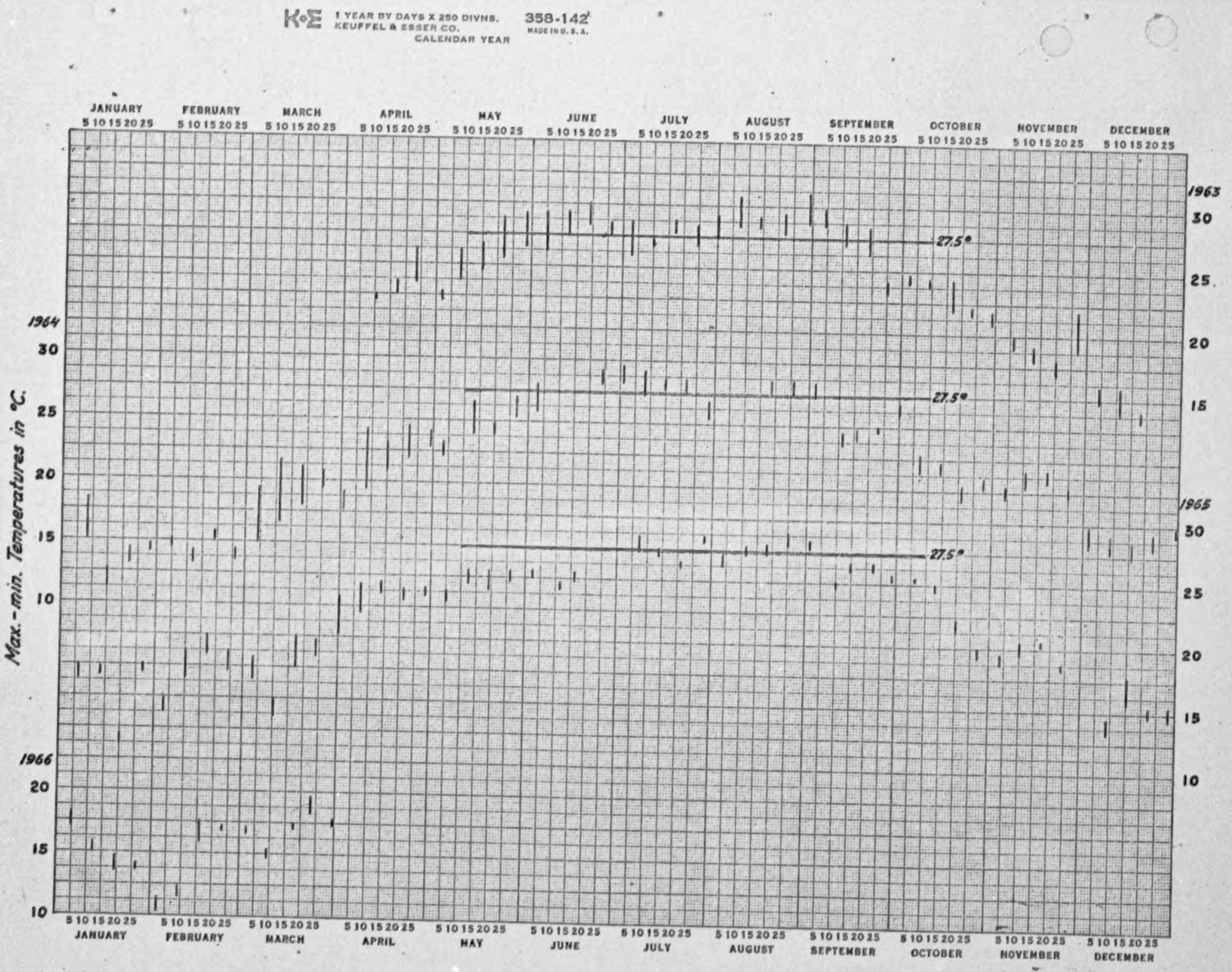
25<

XERO COPY



BIG LAKE TANGERINE

Fig. 3



LAKE ST. CLAIRE

Fig. 4

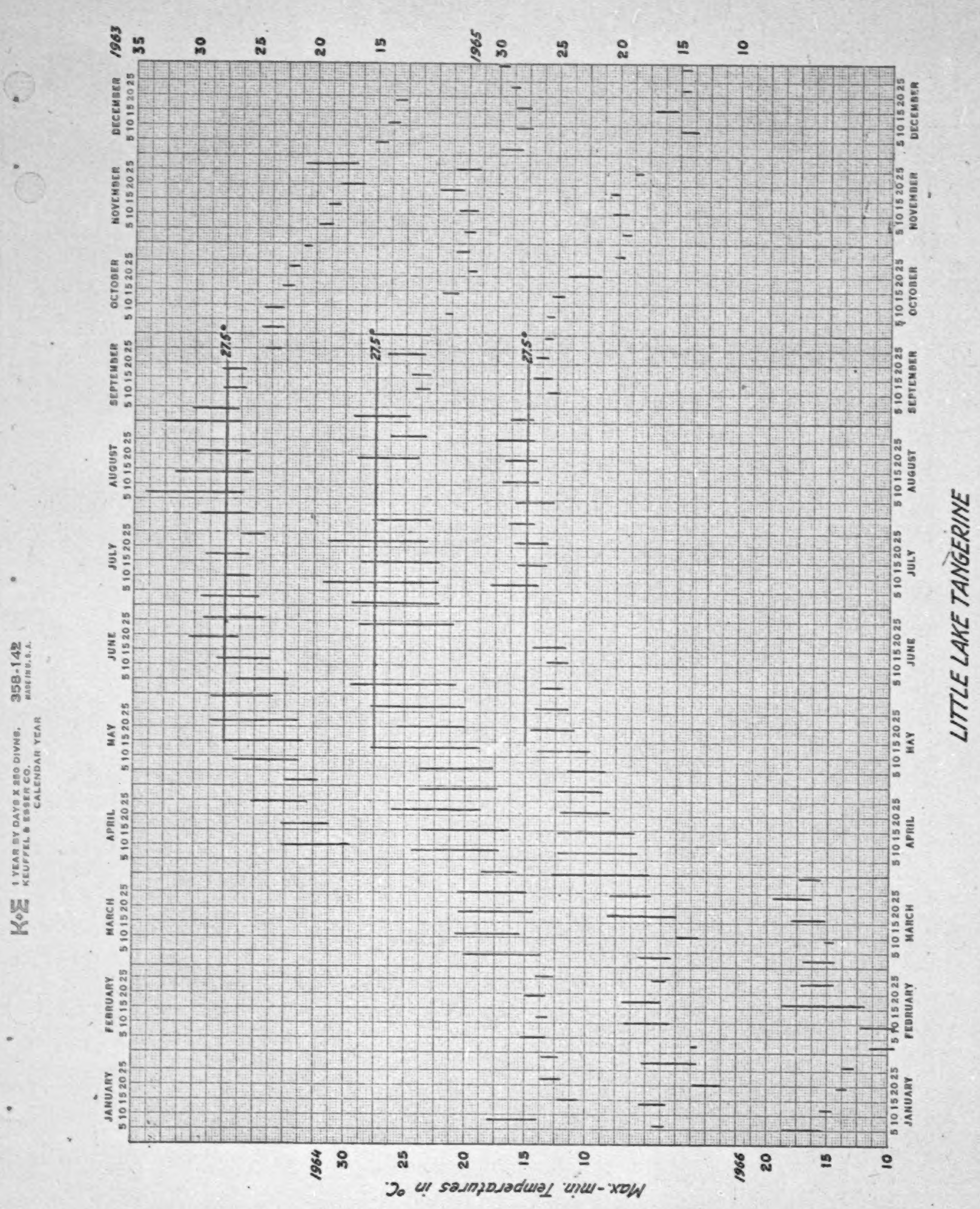
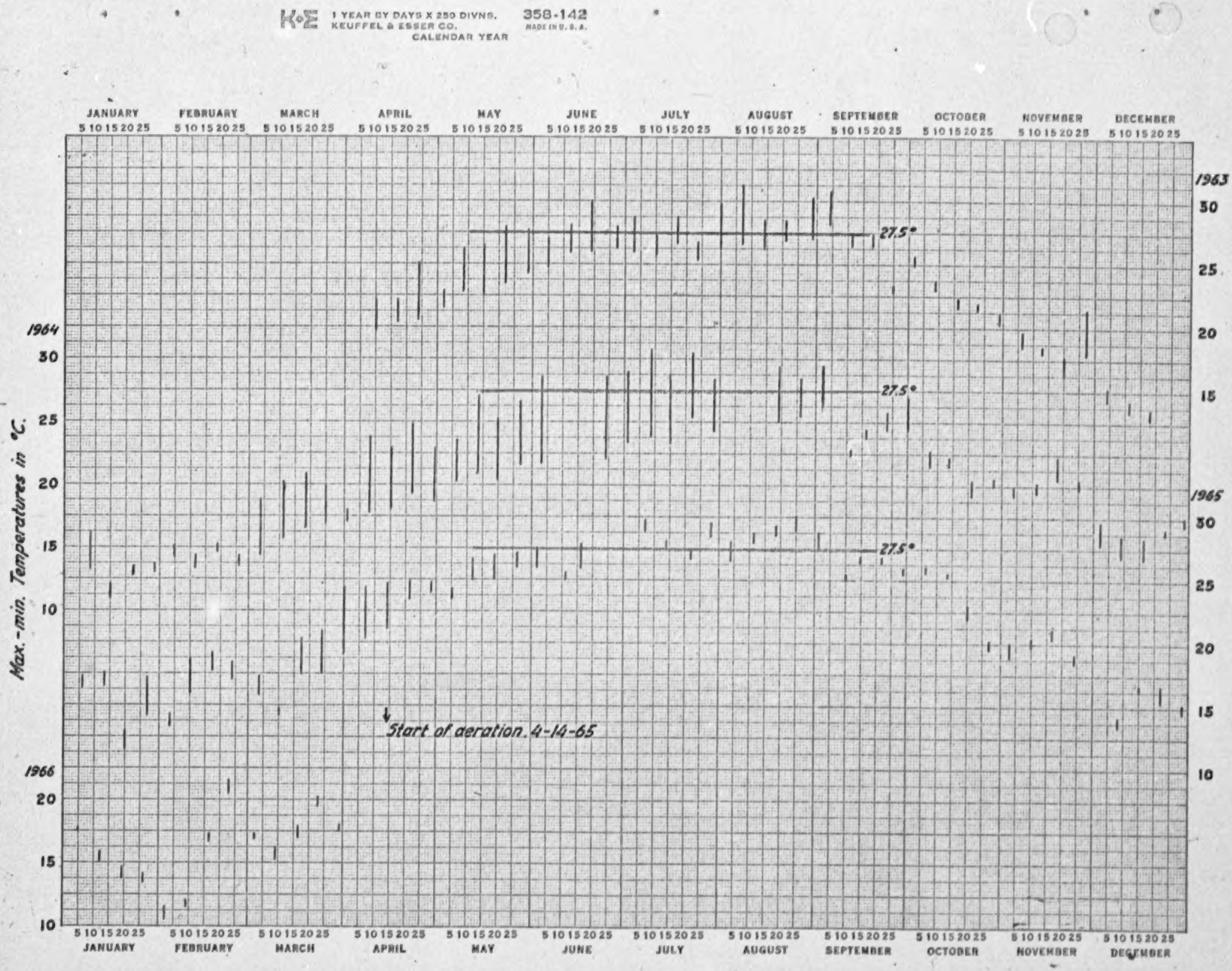
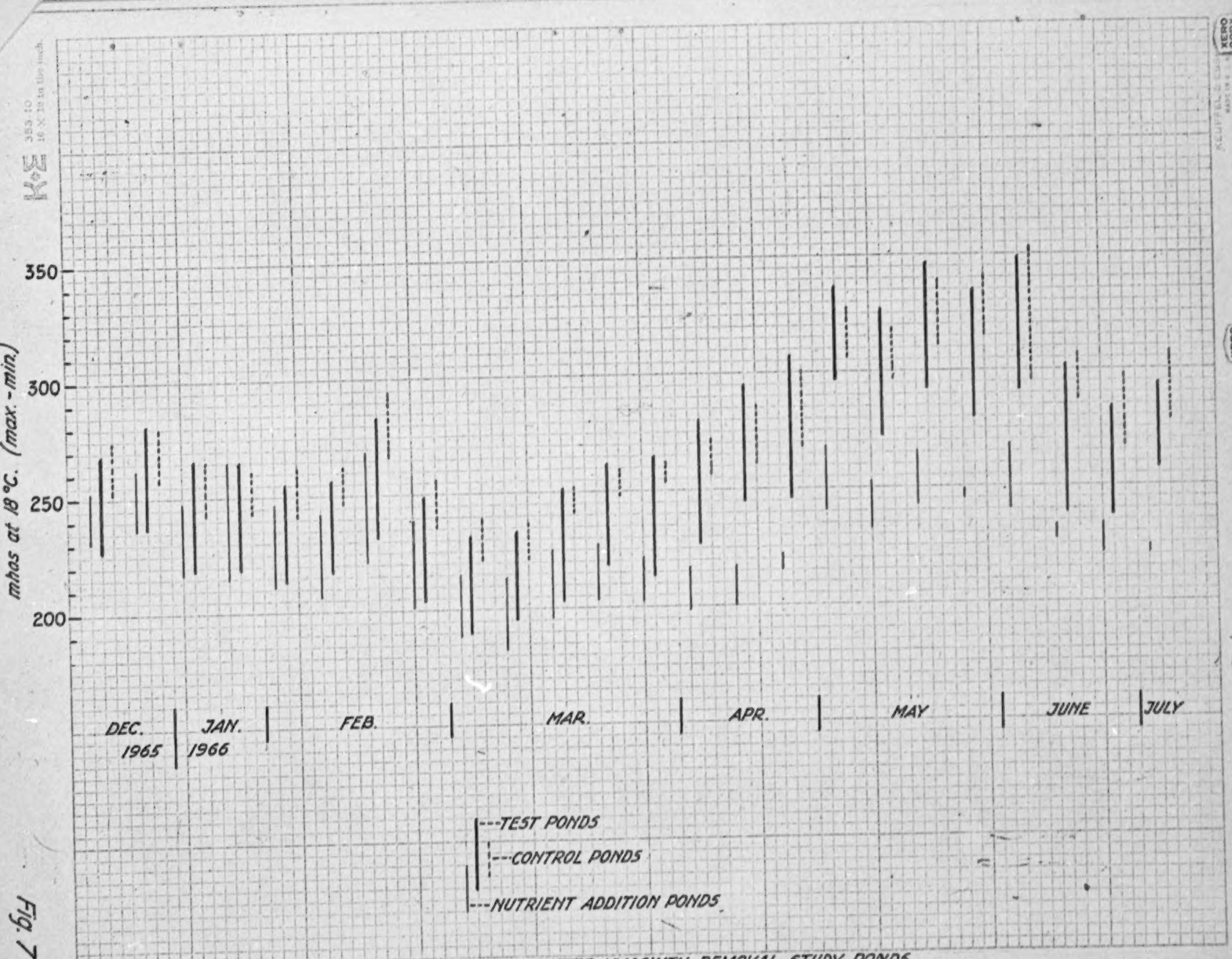

LITTLE LAKE TANGERINE
Max.-min. Temperatures in °C.
1963
1964
1965
1966
35
30
25
20
15
10
27.5°
27.5°
27.5°
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
K&E
1 YEAR BY DAYS X 250 DIVNS.
KEUFFEL & ESSER CO.
CALENDAR YEAR
358-142
MADE IN U.S.A.

Fig. 5



BIG LAKE TANGERINE

Fig. 6



CONDUCTIVITY IN WATER-HYACINTH REMOVAL STUDY PONDS

Fig. 7

Table I. Productivity (dry weight) of *Eichhornia crassipes* in natural ponds.

Salvinia Pond			Airport Pond		
Date	Productivity ($g/m^2/day$)		Date	Productivity ($g/m^2/day$)	
4/23 - 5/7/64	10.92		4/23 - 5/7/64	4.24	
	6.88			3.64	
	7.08			7.10	
average		8.29	average		4.99
5/7 - 5/15	1.76		5/7 - 5/15	6.04	
	0.72			9.92	
	2.12			8.52	
average		1.53	average		8.16
5/15 - 5/21	3.76		5/15 - 5/21	1.88	
	1.88			5.68	
	0.96			6.60	
average		2.20	average		4.72
5/24 - 5/28	4.04		5/24 - 5/28	7.28	
	2.44			4.84	
	2.44			6.48	
average		2.97	average		6.20
5/28 - 6/4	0.80		5/28 - 6/4	1.60	
	3.24			0.80	
	1.60			0.00	
average		1.88	average		0.80
6/4 - 6/11	4.04		6/4 - 6/11	10.52	
	3.24			8.92	
	2.84			10.52	
average		3.37	average		9.99
6/11 - 6/18	1.60		6/11 - 6/18	0.00	
	0.00			0.00	
	21.72			0.00	
average		11.99	average		0.00
6/18 - 6/25	1.20		6/18 - 6/25	-12.16	
	4.04			-14.56	
	4.04			-12.16	
average		3.09	average		-12.96
6/25 - 7/16	0.00		6/25 - 7/16	0.00	
	0.00			3.12	
	0.00			1.36	
average		0.00	average		1.49

Table II. Obvious Leaks Noticed in Ponds

Date	Pond No.	Amount of leakage where noted
6/7-6/10/63	1	5-6"
6/20	7	-
9/4	12	completely
10/18	14	-
10/18	2	-
10/18/63	10	-
	Series 2, ponds 1-14	
1/3/64	7	badly
1/17	8	"
4/25	Y	3 & 3/4"
4/30	X	2 & 3/4"
5/11	X	badly
5/11	Y	badly
6/24	W	badly
7/5	Y	badly
7/21	X	completely
7/21	Y	"
7/21	Z	"
8/4	10	4"
8/4	3	-
8/4	3A	-
8/26/64	5	-
	Series 3, ponds 5-14	
4/21/65	5	-
	Series 4, ponds 1-10	
4/4/65	8	badly
4/21	7	badly
	Series 5, ponds 5-14	
5/11	11	completely
5/11	13	completely
5/11	8	completely
5/25	10	badly
6/1	5	-

Table III. Representative water-hyacinth dry weight productivity, Series 1-5, in grams/m^2/day.

Date	Productivity	Date	Productivity
(Ser. 1	Pond 2)	(Ser. 2	Pond 6)
5/16/63	0.0	12/2/63	0.0
5/31	19.9	12/31	0.5
6/13	56.6	1/6/64	0.0
6/20	56.0	1/22	4.0
6/28	43.4	2/6	- 0.8
7/5	28.4	2/24	3.3
7/17	29.8	3/13	17.4
7/23	9.9	3/25	5.8
8/6	5.7	3/30	- 2.0
8/19	7.6	4/9	7.0
9/3	16.6	4/17	6.8
9/30	8.8	5/4	7.0
10/31	16.8	5/11	12.0
		5/18	9.2
(Ser. 3	Pond 11)	5/27	13.8
12/11/64	0.0	6/3	12.0
1/28/65	2.8	6/10	17.0
2/18	13.2	6/17	7.1
3/11	8.1	6/24	10.6
3/29	8.1	7/1	3.1
4/21	13.3	7/15	13.8
		7/29	12.0
(Ser. 5	Pond 11)	8/18	7.7
5/17/65	0.0	8/26	15.5
6/1	61.6	9/17	2.7

Table IV. Conductivity (mhos at 18° C) in Series 6 ponds. T = test, N = nutrient addition, C = controls.

	12/22/65	12/29	1/5/66	1/19	2/2	2/9	2/16	2/24	3/2
T	269	281	266	265	255	256	283	249	231
	227	236	219	219	213	216	231	204	190
	243	253	243	238	231	231	246	226	209
	248	262	252	245	233	238	253	229	215
C	273	279	264	260	256	255	283	255	232
	271	277	254	264	261	261	293	252	238
	251	265	250	243	242	247	266	242	221
	251	257	247	243	255	249	280	235	226
N	231	236	216	215	210	206	221	201	187
	253	261	247	265	246	242	269	238	215

	3/9	3/16	3/23	3/30	4/15	4/25	4/29	5/6	5/11
T	233	251	261	265	280	295	306	337	327
	195	203	218	213	227	245	246	297	274
	210	228	240	241	252	266	278	324	306
	207	229	240	243	246	273	280	328	311
C	235	250	257	254	263	261	267	306	296
	236	251	258	261	271	285	288	319	318
	226	243	257	257	263	274	284	324	312
	222	242	248	260	257	282	300	327	313
N	183	198	203	203	198	200	215	241	233
	214	225	227	221	216	217	223	268	251

	5/20	5/27	6/3	6/17	6/24	7/8
T	346	335	349	302	283	293
	293	280	291	240	238	258
	314	311	325	288	267	280
	315	313	328	285	269	276
C	312	315	295	288	282	279
	338	340	352	306	298	308
	330	327	343	290	284	286
	319	330	340	288	267	286
N	243	245	240	232	221	222
	266	248	269	228	234	223

Table V. Average water-hyacinth dry weight productivity, Series 6 (grams/m^2/day). Test ponds = hyacinths harvested and thrown away. Control ponds = hyacinths harvested, ground and returned to pond. Nutrient addition ponds = hyacinths harvested and thrown away, and fertilizer added.

Date	Test ponds	Control ponds	Nutrient addition ponds
7/12/65	0.0	0.0	0.0
7/28	19.1	19.9	22.0
8/9	28.2	28.4	25.1
8/26	20.3	26.7	14.6
9/16	10.0	17.6	9.5
10/7	2.7	15.2	4.0
11/4	0.0	11.3	2.9
12/21	0.0	7.3	2.8
1/27/66	0.0	5.9	2.7
4/20	0.0	5.2	5.2
5/12	0.0	20.5	14.6
5/19	4.2	37.2	31.6
5/31	5.4	21.2	15.2
6/21	12.3	18.2	3.9
7/8	10.1	19.8	0.0
8/4	6.5	21.5	3.4
9/1	4.6	17.7	7.5
9/27	0.0	19.8	0.0
10/3	1.9	10.2	2.3

FINAL REPORT

CAUSES AND RELIEF OF HYPER-EUTROPHICATION OF LAKES

Grant Number: WP-00216-06

Former Principal Investigator (and author of main report):

James L. Yount
Chairman, Division of Natural Sciences
Polk Junior College
Bartow, Florida

Principal Investigator (and author of appendix):

Roy A. Crossman Jr.
Biologist
Florida State Board of Health
Winter Haven, Florida

Sponsoring Institution:

Entomological Research Center
Florida State Board of Health
Vero Beach, Florida

APPENDIX

THE BIOLOGY OF *GLYPTOTENDIPES PARIPES*

Roy A. Crossman, Jr.

THE BIOLOGY OF *GLYPTOTENDIPES PARIPES*

By Roy A. Crossman, Jr.

37<

Work under this Grant on the biology of the chironomid *Glyptotendipes paripes* has concerned itself with (1) the emergence of adults, (2) the distribution of egg masses, (3) the numbers and distribution of larvae, (4) general productivity, and (5) attempts at rearing.

I. Emergence Studies

Emergence of adult *Glyptotendipes paripes* was studied by the use of funnel-type emergence traps. These were made according to Jonasson's(1954) discussion. The funnel trap is a cone of copper or plastic window screen, the bottom having an area of 1/4 square meter and the top having a short open neck of copper tube over which the mouth of a quart mason jar is fitted. A reenforcing wire frame holds the jar in position. The entire trap is hung in the free water from a float which is anchored to the bottom. Pupae rising from the bottom are thus funneled into the jar. The entrapped air creates a calm water surface from which the adults emerge. It was in time observed that there were frequently more pupal casts than adults, indicating that neonates were for some reason disappearing from the jar. As of March 29, 1962, the traps were modified; a 3/4-inch plastic hose to pipe adapter was installed in the jar lids, and the funnel neck was modified to receive them. This was done to retain any pupae or adults that fell back through the surface film. In January, 1963, copper fittings replaced the plastic adapters and proved much more serviceable.

Traps were operated in six lakes, as follows. (1) *Lake Hart*. Traps labeled North and South were operated over sand in about 10 feet of water from March 1960 to March 1961. (2) *Lake Buckeye*. Traps labeled East and West were operated over sand-muck in about ten feet of water from September 1959 to December 1962. (3) *Lake Cannon*. Five traps were operated from March 1961 to December 1962 and numbered 1 to 5. Numbers 1 and 2 were over sand in 3 and 5 feet of water respectively. Numbers 3 and 4 were over sand-muck in 10 and 15 feet of water respectively. Number 5, which recovered no pupae nor adults, but did have egg masses adhering to it, was over muck in 20 feet of water. Trap 1 had to be moved to operable depths when changes in lake levels rendered the site too shallow. (4) Lake St. Claire. Seven traps were operated from April, 1963 to March, 1966. The traps were labeled by depth. Trap 3 was over sand and detritus. Trap 6 and traps 9 and 9B were over sand-muck and trap 12 was over muck. The last trap recovered no G. paripes. (5) Little Lake Tangerine. Traps East and West were close together in water about 5 feet deep over sand-muck from May 1963 through March 1966. The traps had to be moved to operable depths with the wide fluctuations in water levels. (6) Big Lake Tangerine. Traps East and West over sand-muck in water about 5 feet deep from May 1963 through March 1966.

The traps were usually emptied five days a week until 1962 when the schedule was changed to three times a week. In servicing the trap, it is drawn to the surface, the jar released and capped under water and then replaced with a jar half-filled with water and dropped back into the lake. In the laboratory the contents of the jars are poured into fingerbowls from which the insect material is removed to alcohol for later identification and counting.

In the following analysis of emergence, only counts of pupal casts are utilized. The disappearance of adults, whatever the cause, rendered adult data erratic and unusable. The pupae which entered the jars and died there were not necessarily on the way to emerging, so they were excluded also. Another feature of the analysis is that it discarded all data from traps serviced at greater intervals than three days. Per day averages for two and three day runs did not vary greatly from counts in traps serviced daily, but starting with four-day runs, there was a marked reduction in the larger pro-rated counts.

Emergence Patterns

On the first three lakes studied, emergence followed a bimodal annual pattern, peaks occurring in Spring and Fall, with midwinter production reduced almost to nil (Table I, Fig. 2). Although there is a suggestion of two generations a year produced, this is probably not the case. Recent successful rearing attempts since the termination of the Grant indicate the possibility of the life cycle being completed in 19 days at 80° and 55 days at 70° (R. A. Crossman, Jr., unpublished data).

In Lake Cannon the trap in 5 feet of water was quite consistently the heaviest producer, followed by the one in 10 feet and then, well behind, the ones in 3 feet and 15 feet (Table II).

The last three lakes studied did not display the same consistent seasonal patterns although in some years some lakes displayed the bimodal pattern (Tables III and IV, Figs. 2 and 3). An explanation for the winter 1964-65 production in Little Lake Tangerine might be a combination of lowered water levels, warm winter, a small lake protected from wind effect and dark bottom deposits to absorbe the radiant heat.

In Lake St. Claire the trap in 6 feet of water was quite consistently the heaviest producer, while the traps at 3 and 9 feet, well behind, were almost equal.

Effect of Moon Phase

A simple analysis of the emergence data from Lake Cannon by moon age (Table V, Fig. 4) reveals a pronounced lunar rhythm. The curve is broadly depressed between first quarter and full moon and sharply elevated about the third quarter. The phenomenon is more pronounced at the 3-foot depth than at any of the greater depths, as would be expected of a light phenomenon in a turbid lake.

Following the discussion of Williams (1937) the geometric means were calculated by the use of logarithms. To accomplish this, the following calculations were undertaken. Since the traps were not serviced daily throughout the study, an arithmetic average-per-day number was calculated for two and three day collections. Longer periods were not considered. Since there were many frattional numbers, the average-per-day number per 1/4 sq. m was multiplied by 161.88 to give an assumed 1/100 acre emergence number, which was a more workable number. Since the logarithm of zero is minus infinity and there were many zero observations, a unit, one, was added to all observations before taking the logarithms.

The logarithms for each moon-age day (0 = new moon) were summed and the mean taken. The antilog-1 was calculated from the average log and used for further presentation.

These antilog-1 numbers were used in Figure 5 to illustrate the average emergence per moon-age day per 1/100 acre from all depths and lakes sampled. Table VI selects from the antilog-1 numbers 8-13 of moon age (summed) and compares that emergence to day 21-26 (summed) along with Secchi disc visibility during the moon cycles studied.

Since emergence occurs mostly during the second hour after sunset, the pattern indicated a depression of emergence when the moon is in the sky and waxing at that time, and a heightened emergence when there is no moon at all in the sky at that time. This is not surprising since lunar emergence rhythms are well known in certain other chironomid species. There is the possibility that an artifact is involved; the rising pupae may avoid the trap's funnel when sufficient light permits it to be more clearly visible. That this is not artifactual may be shown by comparing Lake Cannon 10, 10A, 10B and 10C (Table VI). 10 and 10A were the usual funnel traps. 10B and 10C were placed directly on the bottom. These last two consisted of a metal cylinder, black plastic cone supported by three braces which also held a female pipe fitting to accept the tube jar. This entire unit was drawn to the surface when the jar was changed. Even though the traps 10A, 10B and 10C were not used for as long a period of time (about 7 lunar cycles compared to 17 for the others), and considerable difficulty was encountered with the plastic, the data still reflect the lunar periodicity. Another point in favor of this phenomenon is that the traps at the 3 foot depths for certain periods rested on the bottom as water level fluctuated.

II. Egg Distribution

It was early observed that G. paripes egg masses frequently adhered to the float, the rigging, and the trap itself. On the chance that the numbers of such egg masses might be meaningful, they were counted at all visits to the five Lake

Cannon traps. These data were then available for comparison with emergence itself from the same traps. The seasonal distribution of the egg mass data for Lake Cannon (Table VII) closely corresponds to that of emergence (Fig. 1).

For further investigation of the egg masses, an egg trap was constructed in August of 1963. This consisted of a 1" X 2" cypress frame of either 1/4 or 1m square to which plastic window screen was stapled. Number 9 galvanized wire was formed into a framework which kept the trap 1' off the bottom and also formed an attachment 6" above the center of the trap for a nylon cord which was attached to a 1 quart plastic bottle. A portion of a cement block was added to overcome the bouyancy of the wood. To service this device the float and cord were drawn into the boat until the trap could be secured, then the egg masses were counted and removed. It was assumed that these were G. paripes masses since G. paripes was the predominant midge which laid this type of egg mass in this lake. By visual estimation the trap was then returned to the original site. The traps were originally placed at the compass points and labeled N., E., S., and W. The subscript 1 designates a water depth of about 5' and a distance of approximately 25' from the water's edge. The exact position of these traps had to be varied because of fluctuating water levels. Subscript 2 designates about 10' depth and 150' from shore. Subscript 3 designates about 15' depth and 300' from shore. The character A designates a square meter trap; all the others were 1/4 sq. m. Traps N_1 and N_1A were close to the emergence traps and again coincide with emergence trap activity (Table VIII and Figure 6). Table IX shows the traps close to shore recovered the greatest proportion of the egg masses. Why the North trap recovered so many more masses is not known, unless it might be prevailing wind patterns during the emergence periods. However wind was not studied.

Table X further illustrates the moon phase effect. These numbers were arrived at by the use of logarithms as described above for the emergence traps. Except for the West trap, the shallow water traps which collected the most masses recovered about twice as many during lunar day 21-26 compared to lunar day 8-13.

III. Larval Numbers and Distribution

The larval population on the bottoms of selected lakes was sampled routinely with a 6-inch square Ekman dredge. Bottom samples were brought to the laboratory where they were filtered through fine mesh (40 or 60 mesh) sieves and floated in a heavy sugar solution in order to remove all insect larvae. This larval work was done mostly in 1960; after that year the work was curtailed in favor of intensified emergence studies, personnel limitations unfortunately not permitting both investigations simultaneously.

In some lakes transects were run from the shore towards deep water. The depth and type of bottom was recorded for each sample. In the laboratory all larval material, chironomid and non-chironomid, was identified and the total collection was weighed. The results of these transect studies are given in the discussion of productivity, below, in addition to follows.

In the 1960 transects (Table XI) from Lakes Cannon, Deer and Buckeye, Glyptotendipes paripes was more numerous than all other insects combined in an average of 48% of the collections from all three lakes. Of these collections an average of 67% were taken in sand and 24% in sandy muck; 63% were taken in depths from 5 to 10 feet and 17% in depths from 6" to 4 feet.

On Lakes Cannon, Deer, and Buckeye, two larval samples were taken with some regularity through 1960 at the two limnological stations per lake, (Table XII). Lake Buckeye is the only one where emergence was being concurrently studied (Fig. 1). The peak occurrence of large larvae antedated the peak of emergence by one month. In Lake Cannon, peak numbers of large larvae occurred in mid-winter and mid-summer. This is consistent with the normal occurrence of emergence peaks in Spring and Fall, since these bursts in adult production necessarily and correspondingly diminish the populations of large larvae which produced them.

On Lakes St. Claire, Big and Little Tangerine two dredge hauls each were taken in the vicinity of the emergence traps at St. Claire 6 and 9 feet and Big and Little Tangerine. Again the larval numbers reflect adult activity but not in a refined way. The Lakes Tangerine were particularly difficult to sample because of the detritus-sand-muck mixture.

IV. Chironomid Productivity

The production of chironomids in any lake can be measured in several ways. Usual larval methods are subject to the many handicaps of the Ekman dredge, not least of which is the non-collection of first instars and the poor sampling of seconds. Perhaps the artificial substrate method discussed by Yount (1966) could be used, but it has not been tried in lakes. The emergence method may be more accurate but it suffers from laboriousness, as does the larval technique. The egg method was tried because of its relative ease.

Larval productivity by numbers

The average density of fourth-instar larvae in 1960 for Lakes Cannon, Buckeye, and Deer was, respectively, 1283, 1048, and 651 per square meter at the ten-foot depth. If we assume two generations a year, the annual production for these same lakes in 1960 becomes 2566, 2096, and 1302 fourth-instar larvae per square meter. If 9 generations per year, this number could be 11,547, 9,432 and 5,859.

Adult productivity by numbers

On Lake Cannon the emergence averaged, between April 1961 and March 1962, 11.2 adults per square meter per day at depths from 3 to 15 feet. At the ten-foot depth, the average per day per square meter was 13.3 adults. This latter figure indicates a yearly production of 4855 per square meter. This figure may be compared with the previous year's estimate of 2566-11,547 per square meter based on fourth-instar count (see above).

On Lake Buckeye, the daily production of adults at the ten-foot depth averaged 13.2, 5.8, and 2.8 per square meter in 1960, 1961 and 1962 respectively. The 1960 figure indicates a yearly production of 4818 adults per square meter from the 1302-5,859 larvae arrived at from larval sampling.

44<

It is nevertheless permissible to estimate the likely production of chironomids from a lake such as Cannon. Previous work has demonstrated that of the lake's 335 acres, about 100 produce the midge Glyptotendipes paripes, which means 484,000 square yards or 404,690 square meters. The average daily production for all depths, given above as 11.2 adults per square meter, indicates about 5,000,000 per day on a year-round basis. In a peak month like May 1962 this would increase to 15,000,000 which in turn would indicate peak nights about the moon's last quarter the production from Lake Cannon might reach 50 million.

The five million adults per day on a year-round basis, in turn means about two billion per year. At two milligrams each, this would amount to 4 1/2 tons per year from Lake Cannon. Such computations are subject to considerable error but they nevertheless give some idea of the dimensions considered in such a study as this.

Table XIII considers productivity of G. paripes in the last three lakes studied and compares three methods of estimating midge productivity, egg, larva, and adult. It appears that refinements are needed in some, if not all, methods. Obviously the greater number of adults compared to larvae at one station needs refinement of technique. The stations in Lake St. Claire appear to reasonable correspond, except for 1965-66 at 6' if only 2 generations per year. The more difficult recovery of larvae in the Lakes Tangerine is apparent. Even if there were 9 generations per year, more pupal casts were collected than larvae. Where studied in Little Lake Tangerine the egg method appears reasonable compared to to pupal casts, however, the question arises, are the eggs the result of production of Little Lake Tangerine G. paripes adults or adults from neighboring lakes? (three within 1/2 mile, six within one mile).

V. Miscellaneous Life History Data

Within seconds after emergence from the pupal skin adults take flight from the water surface. They have a reddish color for some time. From Nielsen's

(1962) work the emergence has a peak between 45 and 120 minutes after sunset at a duration of civil twilight of 24 minutes. The newly emerged midges fly with the wind to the shore; the females normally mate with older males during this flight, and in some cases also with new males at least after arriving at the shore. Matings also occur during and shortly after a swarm-like flight which takes place at dawn. During the night and the day the midges stay close to the shore of the lake. At sunset the midges return to the lake where the females deposit the eggs 30-90 minutes after sunset. The spent females and the males return to the shore flying with the wind which enables the males to intercept the newly emerged females on the flight to shore. Copulation is effected by means of a spermatophore which apparently is one of the few such cases reported for the Diptera (Nielsen, 1959). Observations in the laboratory indicate the adults are able to live up to seven days but 24 hours is usual.

Female G. paripes lay their eggs in a hammock-like fashion on the hind femora and then release them to the water as has been described for other chironomids. The gelatinous compact mass soon swells and separates the eggs. There may be from 500 to 1500 eggs in one mass. The mass expands to a kidney-shaped volume of about 5 X 15 mm. This mass soon sinks unless the cord happens to stick to something. The floats of emergence traps, lines and the traps themselves often retain the masses. On the assumption that these masses are from G. paripes (since midges that lay similar egg masses are rare in the lakes studied), G. paripes females lay their eggs over water five to fifteen feet deep and at least up to 300 yards from shore, but the majority of the egg masses were recorded on the egg traps 25 feet from shore.

From laboratory observations one to five days after being laid the egg ruptures longitudinally and the mid-portion of the larva usually emerges first, followed by either the head or rear portions. One to four days are spent within the gelatinous mass. Shortly thereafter tubes are noted everywhere. In one case more tubes were noted on the lighted side of the container. Later most occupied tubes were on the bottom of the container. Sometimes the first small tubes were noted on the underside of the surface film of the water which had a noticeable surface scum. High mortality has occurred in all rearing attempts and conclusions are lacking. However, adults and pupae have been produced 40 days to 279 days after hatching at room temperature. This probably included more than one generation. Recent successful rearing attemptssince the termination of the Grant, indicate the possibility of the life cycle being completed in 19 days at 80° F. and 55 days at 70°F. (R. A. Crossman, Jr., unpublished data).

The modified adult emergence traps also recorded an interesting larval event. Although larvae had been noted occasionally in the jars, in the spring of 1962 large numbers of larvae were noted in the jars in Lake Cannon. This seemed to be related to the lowering of oxygen in the lake. In an attempt to study the possibility of oxygen concentrations having an influence on this movement of larvae, plastic bag dissolved oxygen samples (Fremling, 1964) were taken near the emergence traps in Lakes St. Claire, Big and Little Tangerine. Polyethylene bags were filled with surface water, closed with a rubber band, and encased in a hardware cloth envelope, which rather flattened the plastic bag and dropped to the lake bottom. A nylon cord and float was attached to the hardware cloth. After 48-72 hours the manganous sulfate and sodium azide solutions were introduced into the bags, the contents poured into a DO bottle and returned to the laboratory for final titration. During the period of this later study no large numbers of midge larvae were recovered in the jars and no lengthy period of low O_2 were observed.

From observations in the laboratory the pupal stage may last two days; if it lasts longer than this the adult fails to emerge. In the field the pupae can be seen actively swimming to the surface where once breaking through the surface film the adult quickly emerges.

BIBLIOGRAPHY

Fremling, C. R. 1964. Rhythmic Hexagenia mayfly emergences and the environmental factors which influence them. Verh. Internat. Limnol. 15: 912-916.

Jonasson, Pètur M. 1954. An improved funnel trap for capturing emerging aquatic insects, with some preliminary results. Oikos 5 (2): 179-188.

Nielsen, Erik T. 1959. Copulation f Glyptotendipes (Phytotendipes) paripes Edwards. Nature 184 (Suppl. 16): 1252-1253).

Nielsen, Erik T. 1962. Contributions to the ethology of Glyptotendipes (Phytotendipes) paripes Edwards. Oikos 13 (1): 48-75.

Williams, C. B. 1937. The use of logarithms in the interpretation of certain entomological problems. Ann. Appl. Biol. 5: 404-414.

Yount, J. L. 1966. A method for rearing large numbers of pond midge larvae with estimates of productivity and standing crop. Amer. Midland Nat. 76(1):230-237.

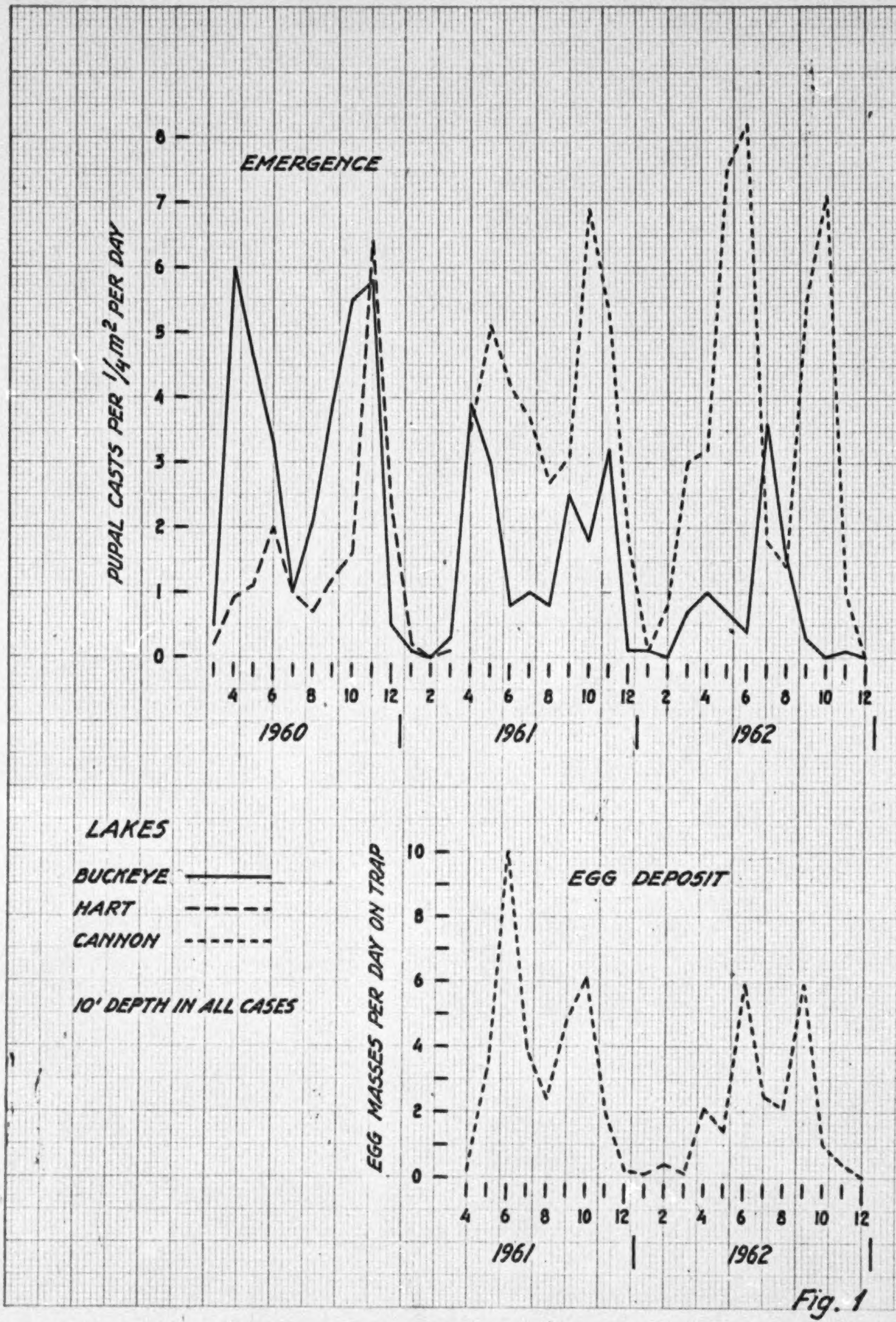

EMERGENCE
PUPAL CASTS PER 1/4 m² PER DAY
0
1
2
3
4
5
6
7
8
4
6
8
10
12
2
4
6
8
10
12
2
4
6
8
10
12
1960
1961
1962
LAKES
BUCKEYE
HART
CANNON
10' DEPTH IN ALL CASES
EGG DEPOSIT
EGG MASSES PER DAY ON TRAP
0
2
4
6
8
10
4
6
8
10
12
2
4
6
8
10
12
1961
1962

Fig. 1

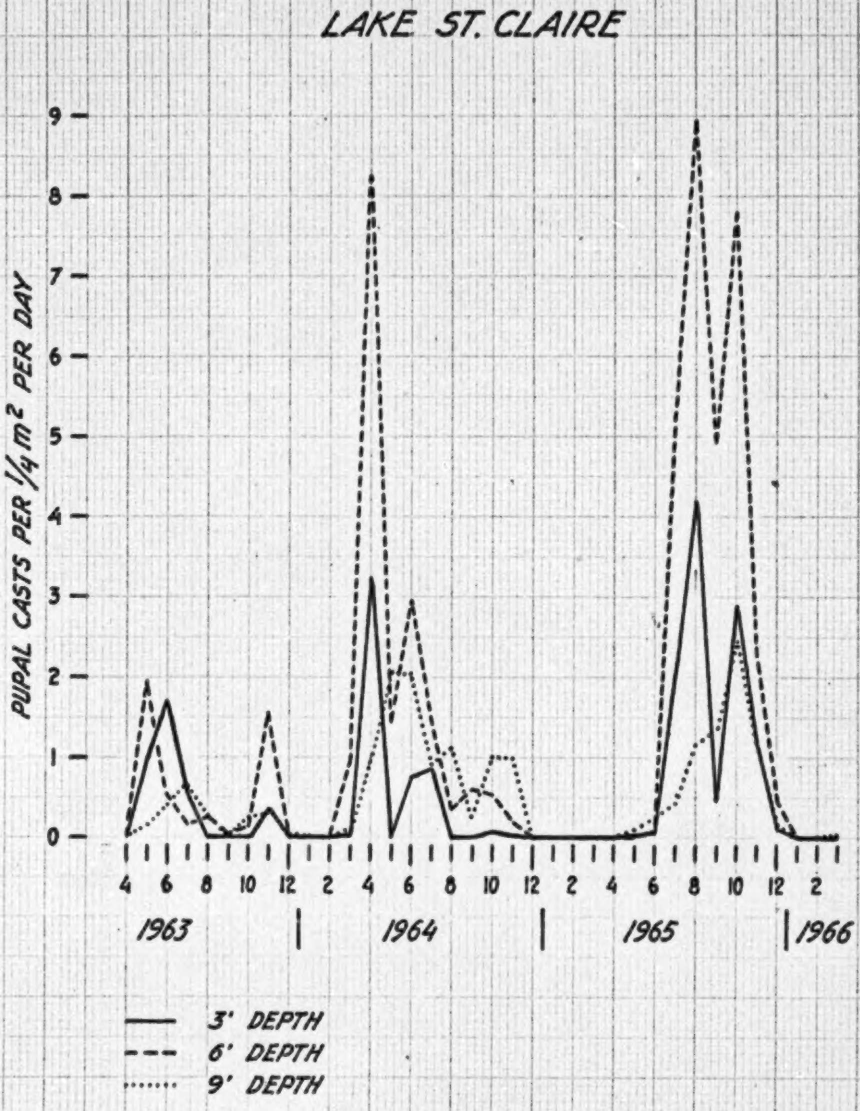

LAKE ST. CLAIRE
PUPAL CASTS PER 1/4 m² PER DAY
0
1
2
3
4
5
6
7
8
9
4
6
8
10
12
2
4
6
8
10
12
2
4
6
8
10
12
2
1963
1964
1965
1966
3' DEPTH
6' DEPTH
9' DEPTH

Fig. 2

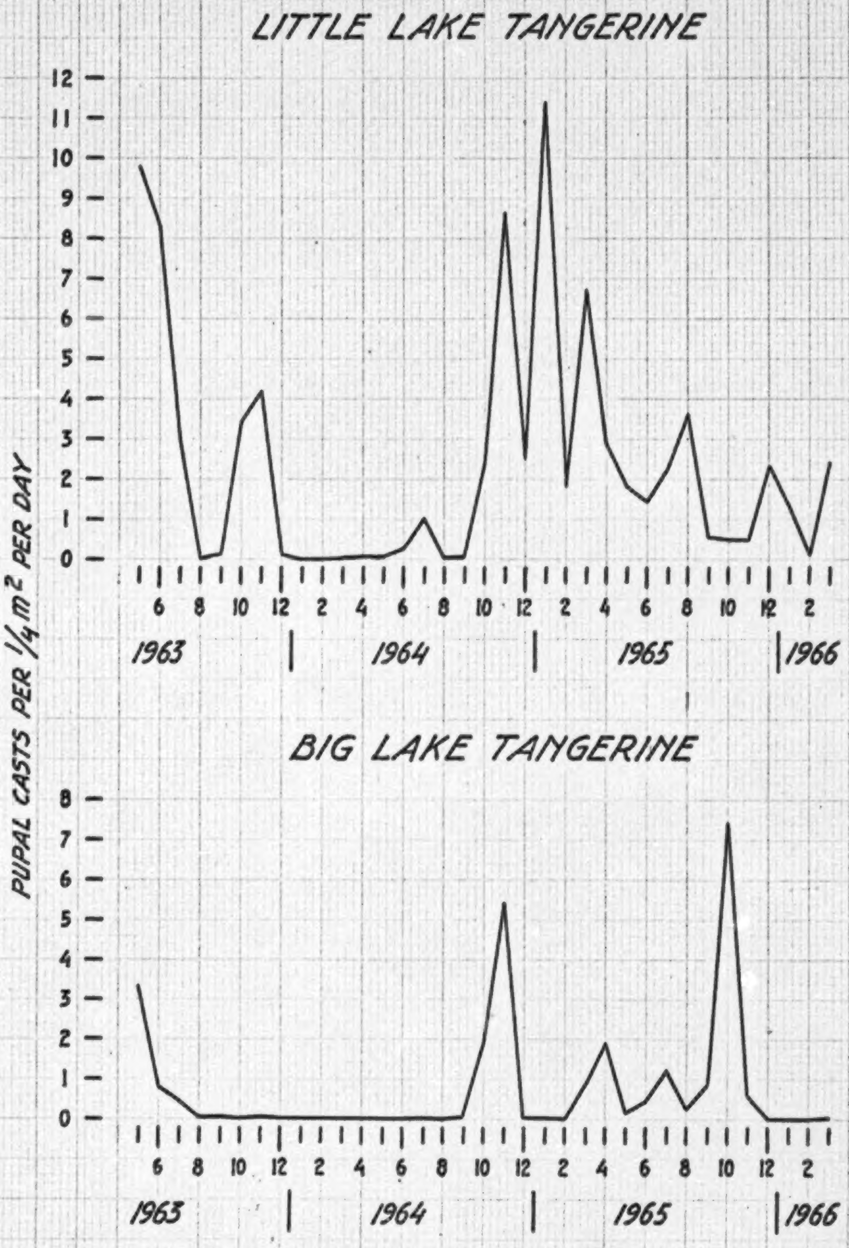
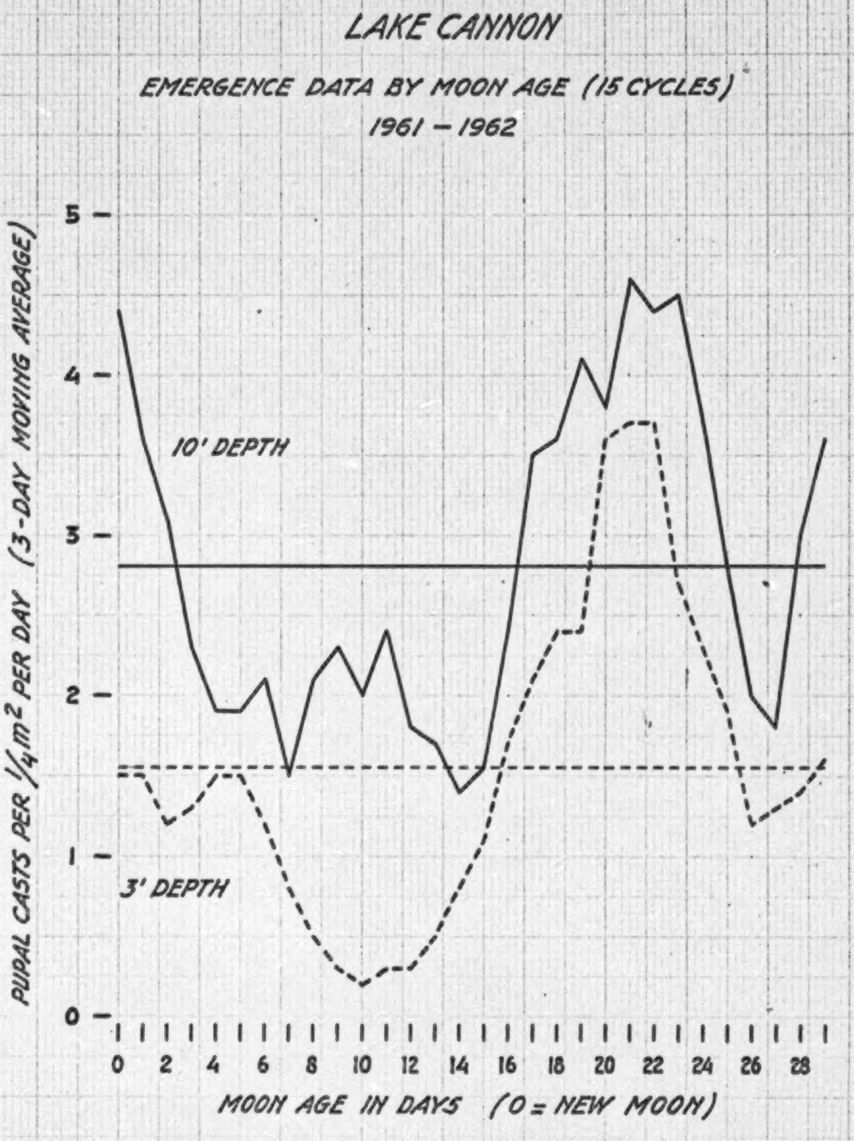


Fig. 3

10 X 10 TO ½ INCH 46 1331
KEUFFEL & ESSER CO.

XERO COPY XERO COPY XERO COPY XERO COPY



LAKE CANNON

EMERGENCE DATA BY MOON AGE (15 CYCLES)

1961 – 1962

Fig. 4

XERO COPY
XERO COPY
XERO COPY
XERO COPY

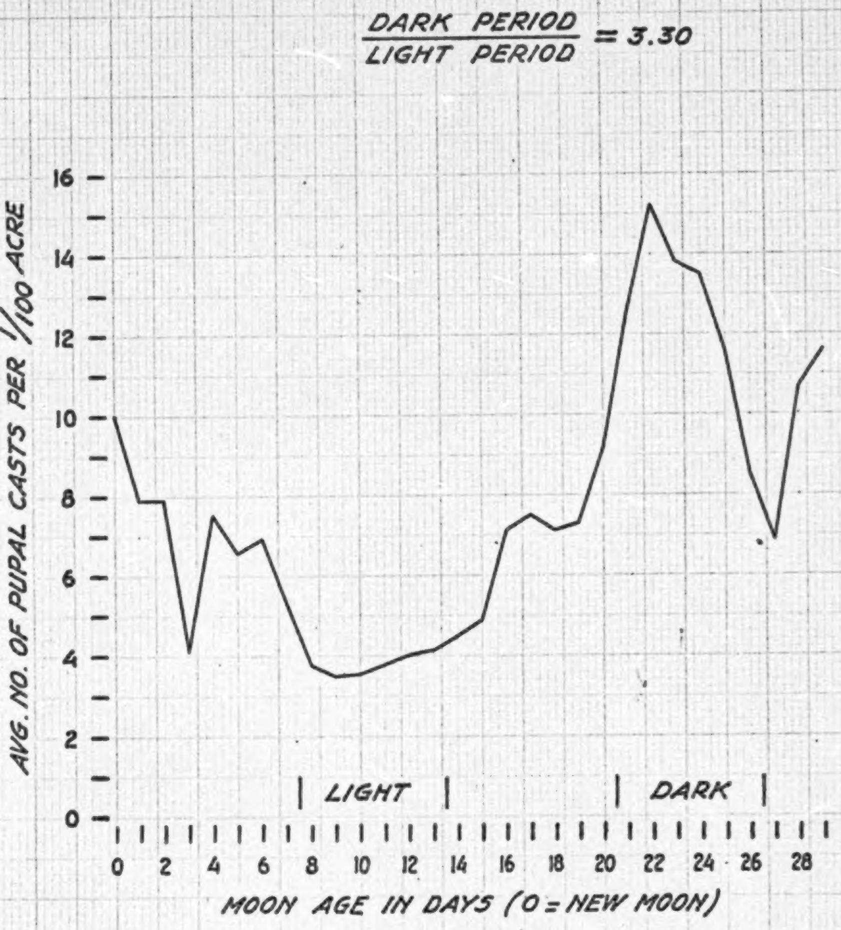


Fig. 5

XERO COPY XERO COPY XERO COPY XERO COPY

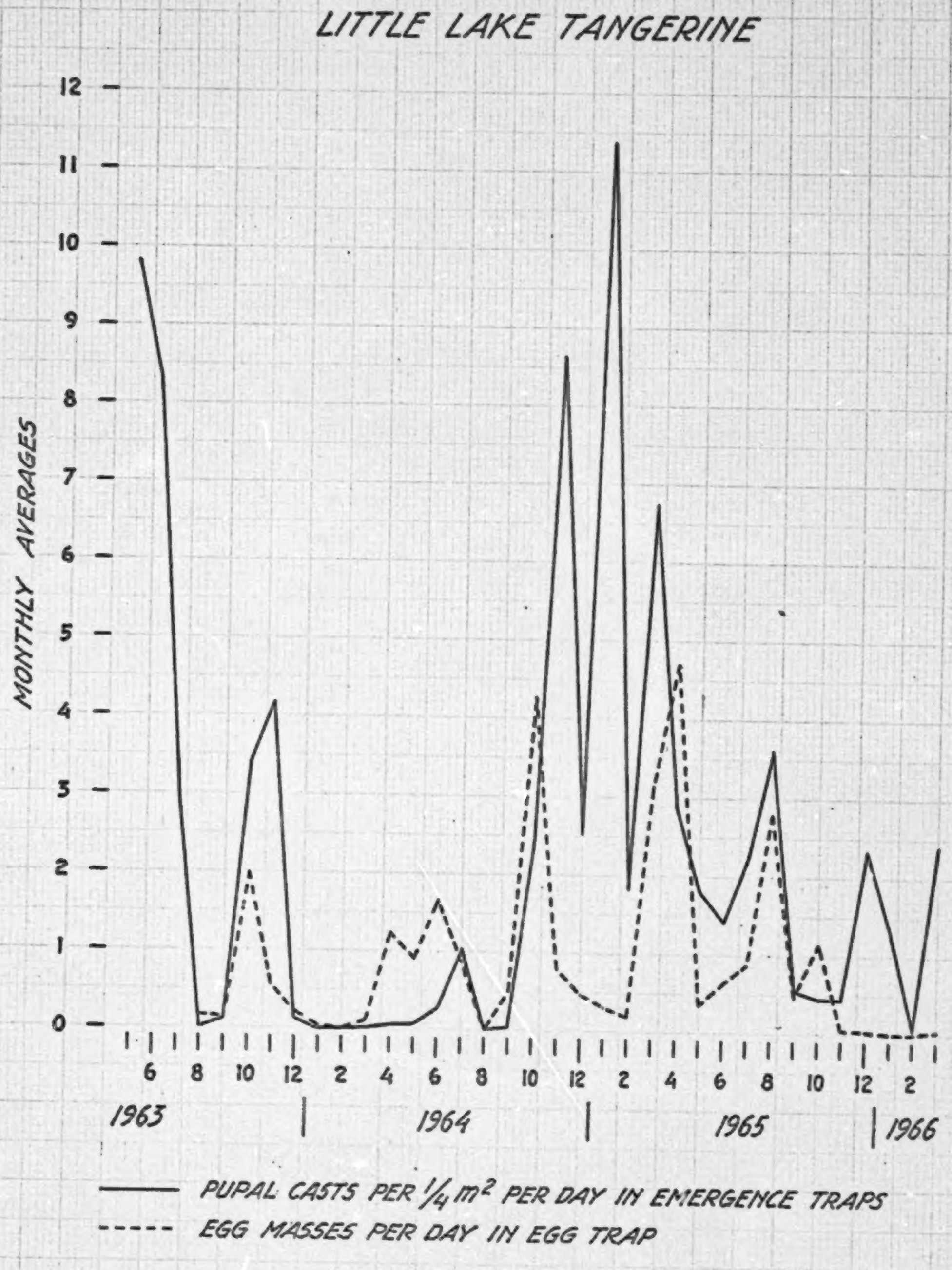


Fig. 6

XERO COPY XERO COPY XERO COPY XERO COPY

Table I. Emergence data for 10-foot depth in lakes Cannon, Buckeye, and Hart, October 1959 to December 1962. Casts per 1/4 m^2 per day.

Month	Cannon	Buckeye	Hart
1959			
Oct.		8.7	
Nov.		8.3	
Dec.		1.5	
1960			
Jan.		.2	
Feb.		-	
Mar.		.5	.2
Apr.		6.0	.9
May		4.6	1.1
June		3.3	2.0
July		1.0	1.0
Aug.		2.1	.7
Sept.		3.9	1.2
Oct.		5.5	1.6
Nov.		5.8	6.4
Dec.		.5	2.3
1961			
Jan.		.1	.2
Feb.		.0	.0
Mar.		.3	.1
Apr.		3.5	3.9
May	5.1	3.0	
June	4.2	.8	
July	3.7	1.0	
Aug.	2.7	.8	
Sept.	3.1	2.5	
Oct.	6.9	1.8	
Nov.	5.3	3.2	
Dec.	1.8	.1	
1962			
Jan.	.1	.1	
Feb.	.8	.0	
Mar.	3.0	.7	
Apr.	3.2	1.0	
May	7.5	.7	
June	8.2	.4	
July	1.8	3.6	
Aug.	1.4	1.5	
Sept.	5.5	.3	
Oct.	7.1	.0	
Nov.	1.0	.1	
Dec.	.0	.0	

Table II. Emergence data for 3, 5, 10, and 15 foot depths in Lake Cannon, April 1961 to December 1962.

		Pupal casts per 1/4 m^2 per day				
		3'	5'	10'	15'	Average
1961	Apr.	10.4	2.5	3.3	.6	4.1
	May	.8	.3	5.1	.0	1.6
	June	.1	4.4	4.2	.0	2.3
	July	1.9	6.0	3.7	.0	2.9
	Aug.	2.2	6.0	2.7	.3	2.8
	Sept.	7.3	6.7	3.1	.2	5.6
	Oct.	3.0	13.5	6.9	2.7	6.4
	Nov.	4.4	10.2	5.3	2.4	5.5
	Dec.	.5	1.3	1.8	.5	1.0
1962	Jan.	.2	.0	.1	.1	.1
	Feb.	.2	.0	.8	.2	.3
	Mar.	1.2	.0	3.3	2.0	1.6
	Apr.	.3	.1	3.2	1.6	1.3
	May	5.2	20.9	7.5	.4	8.0
	June	1.3	17.5	8.2	3.1	7.3
	July	1.5	21.3	1.8	.7	6.3
	Aug.	.3	8.1	1.4	1.3	2.8
	Sept.	.3	16.6	5.5	1.1	6.4
	Oct.	.1	8.5	7.1	2.8	4.6
	Nov.	.2	.1	1.0	1.3	.6
	Dec.	.0	.0	.0	.0	.0

Table III. Emergence data for Lake St. Claire, April 1963 through March 1966, at various depths and stations. Casts per 1/4 m^2 per day.

Date	3'	6'	9'	9'A	9'B	Avg. 9' & 9'B	9'C	Avg. 9'A & 9'C	Avg. 3' & 6' $\left(\frac{9' + 9'B}{2}\right.$
1963									
April	.0	.0	.0	.0	.0	.0	.0	.0	.0
May	.97	1.94	.29	.03	.03	.16	.0	.02	1.54
June	1.70	.53	.63	.53	.17	.40	.33	.43	.88
July	.55	.16	.94	.48	.42	.68	.0	.24	.46
August	.0	.25	.29	.06	.26	.28	.13	.10	.18
September	.0	.03	.0	.03	.0	.0	.0	.02	.01
October	.0	.13	.23	.23	.23	.23	.90	.57	.12
November	.37	1.57	.50	.41	.10	.30	.0	.21	.75
December	.0	.0	.0	.10	.05	.03	.0	.05	.01
1964									
January	.0	.0	.0	.0	.0	.0	.0	.0	.0
February	.0	.0	.0	.0	.0	.0	.0	.0	.0
March	.03	.97	.09	.06	.13	.11	.0	.03	.37
April	3.23	8.25	1.13	2.47	.73	.96	.13	1.30	4.15
May	.0	1.45	1.76	.71	2.32	2.04	.19	.45	1.16
June	.77	2.94	1.83	.88	2.25	2.04	.10	.49	1.92
July	.87	1.47	1.02	.19	.81	.92	.52	.36	1.09
August	.0	.36	1.00	.79	1.21	1.11	.50	.65	.49
September	.0	.60	.27	.27	.27	.27	.03	.15	.29
October	.08	.53	.89	.98	1.12	1.01	.17	.58	.55
November	.02	.19	.73	.67	1.24	.99	.26	.47	.40
December	.0	.0	.06	.0	.0	.03	.03	.02	.01
1965									
January	.0	.0	.0	.0	.0	.0	.0	.0	.0
February	.0	.0	.0	.0	.0	.0	.0	.0	.0
March	.0	.0	.0	.0	.0	.0	.0	.0	.0
April	.0	.0	.0	.0	.0	.0	.0	.0	.0
May	.03	.0	.10	.0	.10	.10	.0	.0	.04
June	.05	.09	.05	.29	.43	.24	.10	.20	.13
July	2.03	5.30	.46	.36	.42	.44	.0	.18	2.59
August	4.19	8.93	1.65		.71	1.18			4.77
September	.46	4.92	.94		1.81	1.38			2.25
October	2.89	7.79	2.16		2.74	2.45			4.38
November	1.19	2.27	1.22		1.18	1.20			1.55
December	.11	.48	.13		.21	.17			.25
1966									
January	.0	.0	.0		.0	.0			.0
February	.0	.0	.0		.0	.0			.0
March	.0	.0	.06		.0	.03			.01

Table IV. Emergence data for Lakes Big (BT) and Little Tangerine (LT), May 1963 through March 1966, at east (E) and west (W) stations. Casts per 1/4 m^2 per day.

Date	LT E	LT W	Avg.	BT E	BT W	Avg.
1963						
May	8.76	10.83	9.80	3.03	3.62	3.33
June	5.82	10.83	8.33	.54	1.07	.81
July	1.27	4.61	2.94	.33	.55	.44
August	.0	.0	.0	.0	.10	.05
September	.0	.23	.12	.0	.07	.04
October	.66	6.16	3.41	.0	.0	.0
November	2.43	5.93	4.18	.03	.07	.05
December	.28	.0	.14	.0	.0	.0
1964						
January	.0	.0	.0	.0	.0	.0
February	.0	.0	.0	.0	.0	.0
March	.03	.0	.02	.0	.0	.0
April	.0	.13	.07	.0	.0	.0
May	.0	.15	.08	.0	.0	.0
June	.08	.49	.29	.0	.0	.0
July	.0	2.06	1.03	.0	.03	.02
August	.0	.0	.0	.0	.0	.0
September	.0	.10	.05	.0	.13	.07
October	.52	4.29	2.41	.84	2.96	1.90
November	5.20	12.03	8.62	2.07	8.74	5.41
December	3.85	3.19	2.52	.03	.03	.02
1965						
January	11.58	11.17	11.38	.0	.03	.02
February	1.24	2.40	1.82	.0	.0	.0
March	1.29	12.16	6.73	.84	.87	.86
April	2.07	3.70	2.89	.80	3.00	1.90
May	1.39	2.23	1.81	.10	.23	.17
June	1.38	1.48	1.43	.71	.14	.43
July	1.42	2.99	2.21	1.51	.92	1.22
August	.29	6.90	3.60	.19	.29	.24
September	.27	.83	.55	.35	1.52	.94
October	.60	.34	.47	6.08	8.73	7.41
November	.85	.07	.46	.40	.77	.59
December	2.50	2.13	2.32	.0	.0	.0
1966						
January	.06	2.58	1.32	.0	.0	.0
February	.11	.04	.08	.0	.0	.0
March	3.48	1.32	2.40	.03	.10	.07

Table V. Emergence data from Lake Cannon by age of moon within phase, 1961 - 1962, 15 cycles.

Moon Age	Casts per 1/4 m^2 per day (3-d. moving average)				
(days)	3'	5'	10'	15'	Average
0	1.5	7.4	4.4	.9	1.0
1	1.5	5.1	3.6	1.0	1.0
2	1.2	4.5	3.1	1.9	.9
3	1.3	3.4	2.3	1.0	.7
4	1.5	3.2	1.9	.7	.5
5	1.5	3.8	1.9	.6	.7
6	1.2	4.1	2.1	.6	.8
7	.8	3.7	1.5	.5	.6
8	.5	2.8	2.1	.5	.5
9	.3	3.6	2.3	.7	.4
10	.2	3.8	2.0	.9	.8
11	.3	4.6	2.4	.9	.5
12	.3	4.7	1.8	.6	.8
13	.5	6.1	1.7	.4	.6
14	.8	4.3	1.4	.4	.8
15	1.1	4.9	1.8	.4	.7
16	1.7	4.5	2.4	.5	.6
17	2.1	5.7	3.5	.8	1.0
18	2.4	6.8	3.6	.9	1.4
19	2.4	6.6	4.1	1.1	1.0
20	3.6	6.1	3.8	1.1	1.1
21	3.7	5.9	4.6	1.4	1.5
22	3.7	6.8	4.4	1.2	1.3
23	2.7	7.0	4.5	1.7	1.3
24	2.3	6.9	3.7	1.3	1.3
25	1.9	6.3	2.8	1.1	.9
26	1.2	6.0	2.0	.7	.8
27	1.3	6.0	1.8	.6	.8
28	1.4	7.7	3.0	.8	.9
29	1.6	7.5	3.6	1.0	1.6

Table VI. Total of Avg./Day (Antilog-1) G. paripes Casts

Lake	Day 8-13 of moon age	Day 21-26 of moon age	Ratio dark-light	Secchi during moon cycles studied max	min	mean
St. Claire	(33+ Lunar Cycles)					
3	5.87	25.22	4.30	14'+	2'3"	6'4"+
6	16.79	69.87	4.16	(Total obs. 441)		
9	10.40	47.30	4.55			
9B	8.03	29.18	3.63			
9A	10.70	20.89	1.95			
9C	1.47	5.55	3.78			
Little Tangerine						
E	44.76	95.85	2.14	6'	1'4"	3'2"
W	87.82	195.04	2.22			
Big Tangerine						
E	6.13	14.69	2.40	6'11"	1'6"	3'4"
W	5.48	31.17	5.69			
Cannon	(15+ Lunar Cycles)					
3	21.66	156.55	7.23	6'9"	2'0"	4'2"
5	202.75	522.56	2.58	(Total obs. 328)		
10	274.06	1,575.28	5.75			
10A	922.14	3,024.06	3.29			
10B	806.69	2,759.96	3.42			
10C	803.65	879.61	1.09			
15	67.84	137.30	2.02			
Buckeye	(26+ Lunar Cycles)					
B	29.65	103.03	3.47	10'7"	1'7"	6'2"
W	27.28	96.40	3.53	(Total obs. 655)		

Table VII. Egg masses on emergence traps per trap per day in Lake Cannon, April 1961 to December 1962.

	Egg masses per trap per day					
	3'	5'	10'	15'	20'	Average
1961						
Apr.	.3	1.1	.2	.1	.0	.4
May	.2	1.0	3.3	.2	.1	1.0
June	.6	3.7	10.0	.8	.6	3.1
July	.7	8.2	3.9	.0	.1	2.6
Aug.	.6	7.2	2.4	2.1	.0	2.5
Sept.	.4	4.8	4.8	1.0	.2	2.2
Oct.	.6	1.1	6.1	3.4	1.7	2.6
Nov.	1.3	1.4	2.0	.6	.1	1.1
Dec.	.1	.1	.2	.0	.2	.1
1962						
Jan.	.0	.0	.1	.0	.0	.1
Feb.	.0	.0	.4	.1	.1	.1
Mar.	.0	.0	.1	.2	.0	.1
Apr.	.0	.2	2.1	.8	.1	.6
May	.0	1.4	1.4	.3	.1	.6
June	.0	5.2	5.9	3.4	.0	2.3
July	.0	3.1	2.5	1.0	.0	1.3
Aug.	.0	4.6	2.1	3.1	1.8	2.3
Sept.	.1	16.7	5.9	17.5	4.6	9.0
Oct.	1.0	8.9	1.0	2.6	2.8	3.3
Nov.	.1	.1	.4	.4	.1	.2
Dec.	.0	.0	.0	.0	.0	.0

Table VIII. Egg Traps - Little Lake Tangerine
Monthly Average

Date	N_1	$\frac{N_1A}{4}$	E	N_2	$\frac{N_2A}{4}$	N_3	S_3	S_2	W	S_1
1963										
August	.18	.11	.12	.0	.05	.06	.12	.0	.14	.0
September	.13	.09	.03	.03	.01	.0	.0	.03	.36	.03
October	1.98	2.21	1.77	.10	.15	.03	.13	.94	2.77	.74
November	.57	.80	.67	.10	.19	.07	.17	.13	.57	1.00
December	.22	.17	.20	.05	.01	.0	.15	.0	.0	.13
1964										
January	.03	.08	.04	.0	.02	.03	.04	.04	.0	.04
February	.01	.01	.02	.02	.07	.0	.10	.06	.03	.03
March	.12	.07	.20	.11	.05	.10	.10	.17	.13	.29
April	1.23	.48	.97	.17	.13	.10	.17	.13	.64	.20
May	.91	.52	.47	.05	.05	.03	.0	.0	.21	.11
June	1.67	2.42	.61	.01	.0	.12	.0	.0	.15	.19
July	.87	.40	.0	.03	.01	.02	.0	.0	.10	.81
August	.0	.05	.0	.0	.02	.0	.07	.0	.0	.14
September	.50	.28	.10	.10	.02	.0	.0	.0	.27	.67
October	4.27	4.81	.44	.09	.17	.10	.09	.08	6.06	.26
November	.79	.62	.21	.34	.23	.19	.21	.16	.30	.53
December	.48	.92	.0	.31	.16	.13	.06	.13	.21	.23
1965										
January	.31	1.19	.13	.24	.18	.26	.06	.16	.18	.13
February	.19	.05	.04	.07	.01	.04	.04	.0	.04	.0
March	3.13	3.86	.19	.03	.03	.03	.06	.0	.06	1.35
April	4.70	4.65	1.00	.03	.0	.0	.0	.0	.90	3.47
May	.35	1.00	1.23	.0	.0	.0	.03	.0	.06	1.06
June	.62	.83	.43	.0	.0	.0	.0	.0	.14	.79
July	.88	.74	1.94	.0	.0	.12	.0	.0	.65	.12
August	2.79	2.17	1.49	.0	.0	.06	.0	.0	.35	.13
September	.48	1.62	.05	.0	.0	.0	.0	.0	.46	.75
October	1.13	1.21	.23	.03	.10	.0	.0	.0	.45	.37
November	.03	.19	.01	.16	.03	.10	.23	.30	.23	.10
December	.03	.13	.13	.06	.06	.0	.0	.10	.18	.10
1966										
January	.0	.02	.0	.0	.02	.0	.0	.0	.0	.0
February	.0	.07	.07	.04	.01	.04	.0	.0	.0	.0
March	.03	.07	.10	.0	.04	.03	.0	.0	.03	.10

Table IX. Egg Traps 1963-1966 Total Collection

Date	N_1	$N_1A/4$	E	N_2	$N_2A/4$	N_3	S_3	S_2	S_1	W
1963	84	100	82	8	12	4	14	34	57	117
1964	306	281	83	38	11	22	24	23	63	249
1965	429	500	200	16	12	21	11	17	236	105
1966	1	5	5	1	2	2	0	0	3	1
Total	820	886	370	63	37	49	49	74	356	472

Table X. Total of Avg/Day (Antilog-1) Egg Masses (29 Lunar Cycles) by Moon Age.

	Day 8-13	Day 21-26	Ratio Dark-light
N_1	30.11	59.70	1.98
N_1A	147.90	511.50	3.46
E	11.43	28.29	2.48
N_2	7.23	3.51	.49
N_2A	15.77	9.28	.59
N_3	3.05	3.54	1.16
S_3	3.54	3.28	.93
S_2	3.73	3.01	.81
S_1	14.91	33.72	2.26
W	16.69	17.03	1.02

Table XI. Occurrence of *Glyptotendipes paripes* in 1960 transects

Lake	Percent of collections dominated by G. *paripes*	Percent occurrence in bottom types						Percent occurrence in various depths			
		Sand	Muck	Peat	Sandy Muck	Sandy Peat	Peaty Muck	6"-4'	5-10'	11-15'	15+
Cannon	45.7	91.6	2.7	0.0	0	5.6	0.0	16.6	61.0	22.3	0.0
Buckeye	55.0	29.2	4.1	8.3	54.2	0.0	4.1	27.6	72.3	0.0	0.0
Deer	44.0	81.0	0.0	0.0	19.0	0.0	0.0	7.0	56.3	22.0	11.0
Average of 3	48.0	67.3	2.3	2.8	24.4	1.9	1.4	17.1	63.2	14.8	3.7

Table XII. Large larvae per dredge sample in three lakes, 1960.

Lake:	Buckeye				Cannon				Deer			
Station:	7		8		9		10		3		4	
Instars:	3	4	3	4	3	4	3	4	3	4	3	4
Feb.					91	51	107	24	4	7	3	5
Mar.	22	19	33	12	18	19	27	15	14	13	15	20
Apr.	4	13	45	22	52	22	58	8	43	18	41	19
May	12	19	19	16	33	24	35	14	46	34	54	26
June	14	5	26	10	45	19	42	24	18	19	16	18
July	12	14	60	15	50	27	43	34	20	25	11	9
Aug.	72	74	37	14	163	174	21	30	36	11	75	13
Sept.	69	27	67	43	61	17	20	56	7	13	-	2
Oct.	16	39	43	32	18	11	22	10	2	1	3	4
Nov.	33	7	14	6	17	6	18	8	11	42	16	2

Table XIII. G. Paripes Productivity - Lake Alfred Lakes

	St. Claire			
Date	6'	9'	LT	BT
Avg. No. Larvae / 1/4 m^2 / Collections				
Apr. 63-Mar. 64	100	78	51	32
Apr. 64-Mar. 65	1,726	1,004	12	13
Apr. 65-Mar. 66	285	204	25	372
Larvae/ 1/4m^2/yr. - if 2 generations				
63-64	200	156	102	64
64-65	3,452	2,008	24	26
65-66	570	408	50	744
Larvae/ 1/4 m^2/yr. - if 9 generations				
63-64	900	702	459	288
64-65	15,534	9,036	108	117
65-66	2,565	1,836	225	3,348
Pupal Casts / 1/4 m^2/ yr.				
63-64	172	66	960	157
64-65	478	285	1,066	256
65-66	905	183	606	394
Egg Mass / 1/4 m^2/yr. - Trap N_1				
63-64			150	
64-65			438	
65-66			336	